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Discussion Paper

Educating Technological Innovators and Technical Entrepreneurs at Canadian Universities

Thomas E. Clarke
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Educating Technological Innovators and Technical Entrepreneurs at Canadian Universities

May 1987

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FOREWORD

Arguments for closer links between universities and industries often stress the advantages of knowledge transfer through research. Most business people, however, are more concerned with the education and training that universities provide for future employees. The Canadian Manufacturers' Association, for example, views the technology derived from collaborative research with universities as secondary to the "longer-term, more important benefit" of the education and training that graduates acquire during such activities (Improving our Industrial Competitiveness: A Science Policy for Canada, 1986, 7). At a time when there is much discussion of closer university-industry ties, it is not surprising that many business people and their associations have a renewed interest in university curricula and are seeking changes to ensure that graduates acquire the basic skills and understanding needed by employers.

Increasingly the success of many firms rests on their ability to adopt and use new technologies. As a result there is a growing awareness — among educators and in the business community -- of the need to educate future managers in the process and management of technological innovation. Similarly, as the significance of entrepreneurship for economic development becomes clearer, this subject, and technical entrepreneurship in particular, is also emerging as a priority for the curriculum. Courses in these subjects are important not only for business students but also for scientists and engineers. An understanding of technical entrepreneurship and technological innovation can greatly help those scientists and engineers who become managers (as most of them do) as well as those who attempt to set up high-technology businesses.

Although the need for such training is apparent, Canadian universities have only recently begun to provide it. This discussion paper reviews courses in the management of technological innovation and technical entrepreneurship that are available at Canadian universities, and examines the issues involved in offering them. As such, it is a case study of how knowledge-intensive economies are challenging universities to broaden the range of intellectual skills cultivated by their curricula -- by encouraging the crossing of disciplinary boundaries — and of the problems that must be overcome in the process.

Educating Technological Innovators and Technical Entrepreneurs at Canadian Universities is the fourth publication from the Science Council's study, "University Science and Technology and Canadian Economic Renewal." Like the study's other research projects, the aim of this project is to assess ways in which universities are responding or could respond to industry's needs. The study is guided by a committee of Science Council members: professors Geraldine Kenney-Wallace (chair), James Cutt, and Jean-Pierre Garant, and Dr Hugh Wynne-Edwards. Dr Gerald W. McIntyre of the Council of Ministers of Education, Canada, participates as an observer.

Dr Philip Enros, a science adviser on staff at the Science Council, is project officer for the study. Thomas E. Clarke and Jean Reavley are president and vice-president, respectively, of Stargate Consultants, an Ottawa-based consulting firm specializing in the management of research and development.

James M. Gilmour
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INTRODUCTION

Canada is losing the battle to remain a self-sustaining industrialized nation. It already fits the definition of a Third World economy in that its main exports are raw materials and natural resources and its main imports are finished products, especially those in high technology categories.

Numerous studies have shown that new technology-based firms have a major positive impact on an economy in terms of net revenues, tax dollars, employment, R&D expenditures, and export sales.[1] Yet Canadians, by and large, are almost totally unaware of the role that science and technology play in driving a modern industrialized economy. This lack of awareness was noted in a recent unpublished study of innovation policies in western Canada, which reported that there is "insufficient public awareness of innovation and entrepreneurship."[2]

In its submission to the National Science and Technology Policy Forum, held in June 1986, the Association for the Advancement of Science in Canada made the point that, "We in Canada are a society of high spenders on technological products without balancing the books through earnings from the development, production and sale of such products." This concern has also been voiced by the Ministry of State for Science and Technology (MOSST) in its background paper for the same Winnipeg forum. MOSST noted that, "Canada has major weaknesses in the high technology sector where the overall trade deficit in 1984 was $12 billion."[3]

Canadians appear content to be merchants, real estate agents, and natural resource exploiters. Our national industrial policy appears to be one of "if they can make it, we don't have to." To maintain this strategy is a formula for economic, if not national, suicide. The most innovative or entrepreneurial Canadians will move to where the industrial action is, most probably the United States, leaving behind the short-sighted, the incompetent, and the trapped.

This view was echoed by the president of Northern Telecom Limited, David Vice, during a guest lecture at Memorial University in 1986, when he made the following points:[4]

- Canada is too complacent about the present and not well prepared for the future;
- when all else is equal, when our competitors also have good technology, good financing, and good plant and equipment, the difference between winning and losing will be management that is dedicated to striving for excellence;
- not only individual industries or companies, but also Canada's future as an industrial nation, will be put at risk if Canadians -- government, management, labour, and society as a whole -- fail to recognize that they are facing a technological revolution that is bringing fundamental changes in human thought and action, and that the new industrial revolution will proceed with or without Canadian participation;
- Canada eventually will lose its position as an industrial nation unless Canadians are prepared to respond swiftly and powerfully to the technological challenge and unless they recognize that what they have been doing, and however well they have been doing it, is not good enough.

Part of the solution to our national malaise about technological innovation and entrepreneurship is education. Students in high school and university must understand the vital impact that science and technology can have on the economic well-being of Canada. In addition, they should be learning about the entrepreneurship and innovation

processes, and how these processes can be managed most effectively. Management researchers such as Yvon Gasse strongly recommend that such education should start at the secondary school level.[5] The Ontario government is moving in this direction with the development of an entrepreneurship course for high school students. They hope to have this course in place at selected schools in 1987-88.

The purpose of the research for this paper, Educating Innovators and Entrepreneurs for the 1990s, was to determine the extent to which Canadian universities are offering courses on technological innovation or technical entrepreneurship to students in engineering, science, and business faculties; to examine the issues involved in offering these courses; and to obtain the views of deans of science, engineering, and business about such courses. The authors also collected information on the impact that developing and teaching these courses had on the careers of the faculty, and on the efforts being made by American universities to provide training in technological innovation and entrepreneurship (see appendix 3).

CHAPTER 1
TECHNOLOGICAL INNOVATION AND TECHNICAL ENTREPRENEURSHIP COURSES

The type of training required for the effective management of technological innovation or technical entrepreneurship is quite distinct from the general management training offered by every Canadian university business school. Many of the course topics found in innovation or entrepreneurship courses (appendices 1, 2, and 3) are not found in general business programs or textbooks.

The many journals and books devoted solely to the management of technological innovation[6] attest to the validity of this distinction. Several have been in publication for the past 20 to 30 years. Two of the oldest journals are the IEEE Transactions on Engineering Management and Research Management. Similar journals exist in the entrepreneurship area. In addition, many conferences on innovation and entrepreneurship are held by organizations such as the European Industrial Research Management Association (Paris), the Industrial Research Institute (New York), the Babson College Center for Entrepreneurial Studies (Wellesley, Massachusetts), and the Canadian Research Management Association (Toronto).

A course on the technological innovation process and its management provides information on how an organization develops a technical concept from an idea to a product or process and on into the marketplace, all in a medium-sized to large company context. Among the topics that might be included are corporate innovation strategy, R&D management, technology transfer, technological forecasting, factors that determine successful innovation, and the development and marketing of new products.

A course on technical entrepreneurship provides the management skills and information that enable a scientist or engineer to establish a business based on a technical idea and to increase the probability of success of an entrepreneurial venture. Such a course is oriented toward the problems of small and medium-sized firms, the technological innovation process, venture capital acquisition, and marketing. Although a separation between innovation and entrepreneurship is made here, a single overview course can deal both with technological innovation and entrepreneurship. Examples of this type of course already exist in Canada and the United States.

Most people readily accept that it is possible to provide training in technological innovation and its management. Many, however, question whether it is possible to teach entrepreneurship. A common argument is that "one can't train entrepreneurs, they are born." This view is naive. If one cannot train entrepreneurs, then it can be argued that one cannot train physicists, doctors, chemists, or lawyers. Each of these occupations requires a person who has an aptitude and interest in the area. There is no difference in the case of an entrepreneur. Unless the person has the aptitude and the interest in becoming an entrepreneur he or she will not be "trainable" as an entrepreneur. As C.R. Reese and P.H. Thurston of the Harvard University Business School have noted, "entrepreneurship is beginning to be perceived as an element of the managerial process rather than a strange activity to be carried out by individuals with warped psyches."[7]

In academic circles, entrepreneurship is beginning to be recognized as a proper discipline, albeit of the integrative type like technological innovation. William A. Sahlman of the Harvard Business School, and developer of its course on entrepreneurial finance, argues that the specialized approaches of individual disciplines can be successfully developed and taught in an entrepreneurship course. The core concepts of

finance, for example, apply in the entrepreneurial situation but specific topics deserve greater and more detailed emphasis.[8]

Robert Ronstadt, of the Babson College Center for Entrepreneurial Studies, states that the question is no longer whether entrepreneurship can be taught (because it already is taught in more than 200 universities in the United States and Canada) but what should be taught and how it should be taught.[9] Ronstadt suggests that courses on entrepreneurship should teach the following topics and skills: fact versus myth about entrepreneurship, reality testing, creativity, ambiguity tolerance, opportunity identification, venture evaluation, venture start-up action, venture strategy, career assessment, environmental assessment, ethical assessment, deal-making, networking, and harvesting. Marketing, finance, and interpersonal communications skills should be added for people with only a technical or scientific background. These skills would also be appropriate for innovators.

For the past decade, Karl Vesper at the University of Washington has been monitoring the development of entrepreneurship courses at universities in Canada and the United States.[10] He notes that in addition to an increased number of well-supported entrepreneurial programs, there are now endowed chairs at a number of universities, and more are cropping up each year. (Vesper, himself, will be occupying a chair of entrepreneurship at the University of Calgary in 1986-87). Vesper also reports that centres for entrepreneurship have been established or are expected to be established at Harvard, Wharton, Arizona, Arizona State, Babson College, Carnegie-Mellon, Case-Western, De Paul, New York University, University of North Carolina, Rensselaer Polytechnic Institute, and Wichita State.

He notes that most schools begin by offering a standard entrepreneurship course consisting of venture design projects, case studies, readings, and lectures. Guest speakers are considered extremely important to the success of the courses. Some universities move on to a second course, such as a "project development" or "incubator" course, in which students help plan the start-up of a real firm.

An example of a project development course was recently offered in Ireland. In 1983, the Shannon Development Company and the National Institute for Higher Education jointly sponsored an experimental program to teach high technology entrepreneurship.[11] The 120-hour course covered the following topics: characteristics and attitudes of the entrepreneur, market selection, finding and evaluating new products, business plan preparation, company organization, founders' team development, founders' team incentives, financial planning for the non-financially trained entrepreneur, financial considerations for the new venture, management of innovative technology-based companies, and available support services. The course also provided presentations by successful entrepreneurs from technology-based companies and critiques of students' business plans.

Twenty-two of the 30 participants completed the course and four new high technology firms were helped during their start-up phase. Comments received from the managing directors of these firms included, "The course was instrumental in the founding of our venture," and, "The course expedited the formation of the venture and was a significant contributor to getting the venture off the ground."

There appears to be no doubt that entrepreneurship, and in particular, technical entrepreneurship can be and is being taught.

CHAPTER 2
ATTITUDES OF CANADIAN DEANS OF ENGINEERING, SCIENCE, AND BUSINESS TOWARD INNOVATION/ENTREPRENEURSHIP TRAINING

Mail and telephone surveys were used to determine the attitudes of deans of engineering, science, and business toward including courses on technological innovation or technical entrepreneurship in the curricula. Sixty-two deans of Canadian universities were contacted. Useful information was received from 48 deans or their representatives. Of these 19 were from engineering, 21 from science and eight from business faculties. The authors also carried out personal interviews with 18 of the 48 respondents.

The deans of engineering and science were asked:

- whether information on the management of technological innovation or technical entrepreneurship should be provided to students as part of their scientific or technical education;
- the reasons for their opinions;
- the format in which the information should be provided;
- whether any barriers to including technological innovation or technical entrepreneurship courses exist.

The business deans were asked whether:

- they felt their undergraduate or MBA students were sufficiently aware of technological advances and the process of technological innovation;
- a course on technological innovation should be compulsory for all undergraduate commerce and MBA students;
- they could respond positively to a request from their science or engineering faculties to develop a course on either technological innovation or technical entrepreneurship.

Table 1 summarizes the answers to the first question put to deans of engineering and science. The figures show that the majority of deans feel that information on the management of innovation or entrepreneurship should be provided as part of a scientific or technical education. Deans of science, however, are more likely to think that this information should be presented in seminar rather than course form.

Comments from Deans of Engineering

Technological Innovation

Twelve deans of engineering felt that courses on technological innovation and its management should be part of the education of their engineering students. Five of the engineering faculties headed by these 12 deans already have courses on entrepreneurship or innovation and a sixth will offer its first innovation course this fall. At least two of the Canadian engineering faculties whose deans did not respond also offer technological innovation courses. Therefore, at least 14 deans of engineering in Canada believe that courses on technological innovation or its management should be a part of the education of engineering students.

Some of the reasons given in support of courses are quoted below:

Technology is changing rapidly. We are engaged in the innovation process and therefore we should lead it, and not just be swept up by it.

Table 1. How Engineering and Science Deans View the Need for Training in Innovation/Entrepreneurship

Need for Training in Innovation	Engineering Deans		Science Deans	
	No. responding	%	No. responding	%
Yes, courses	12	63	12	57
Yes, seminars	1	5	4	19
No need	3	16	5	24
No comment	3	16	-	0
	19	100	21	100

Need for Training in Entrepreneurship	Engineering Deans		Science Deans	
	No. responding	%	No. responding	%
Yes, courses	12	63	13	62
Yes, seminars	2	11	4	19
No need	4	21	4	19
No comment	1	5	-	0
	19	100	21	100

We need to work on young people and provide them with the knowledge to be innovative or entrepreneurial; it won't happen by luck or accident.

If Canada is to develop as a high technology country and survive in this competitive world, we are going to have to have more and more engineers involved in the areas of technological innovation and R&D. (provides a course)

Engineers often move into management as a natural career progression. It would be useful for them to be sensitized to successful management of innovation and R&D.

The technological innovation course has merits other than its contents. In an engineering program, students tend to take courses which are analytic in nature and where every question has an answer, a precise answer, a unique answer. They are rarely confronted in class with situations where several solutions with different consequences are possible. They suppress intuition. This course could give them exposure to such situations which they are likely to encounter later in life.

Some of the supporters of the courses had mixed feelings about including them in the engineering curriculum:

The value of such a course cannot be denied. However, skill in management of technological innovation and R&D are generally not required to be exercised by newly appointed engineers. They should acquire it during the first few years of their working life. Exceptions are those who join small establishments where the few engineers (or only engineer) are expected to do "everything." The universities' duty to the industrial sector can be fulfilled by providing such a course as an elective for engineering students and as an extension course for practising engineers.

One of the deans who did not consider that a technological innovation course should be part of the engineering curriculum stated that:

There is a need for many kinds of information but the curriculum is full. Students must first be competent to do the technological innovation.

Another dean stated that instead of being offered as a separate course, technological innovation should be incorporated into some of the existing engineering courses. This approach was also suggested by a supporter of specific technological innovation courses.

A few deans commented on whether their students would be interested in obtaining information on technological innovation. One dean thought:

The answer is No, and the main reason is the subsidiary employment mentality of the students entering the university for engineering studies. They perceive themselves to be at university for an engineering education and any requirement that takes them into other subjects and fields is not generally well received. It is generally felt that the skills necessary for innovation and R&D management are secondary attributes of an engineer and can be picked up on the job.

Several deans who do have innovation courses commented that students do want this type of information.

The majority of the deans of engineering felt that information on technological innovation should be provided in the form of a single, overview, elective course. Only two believed that courses should be compulsory, and two more that a package of courses similar to that offered by the École Polytechnique de Montréal should be offered.

Another point of general agreement was that courses should be presented by actual innovators. One respondent stated that the course instructor should be, "an inspiring teacher, a motivator with personal experience with innovation." The deans agreed that, if an innovator was not available as an instructor, a team-teaching approach would suffice, with an enthusiastic, knowledgeable person leading the course and with innovators as guest lecturers. The involvement of innovators was considered vital to the success of a course.

Technical Entrepreneurship

Twelve deans of engineering stated that information on technical entrepreneurship should be provided to engineering students as part of their education. Four engineering faculties currently offer technical entrepreneurship courses and another is exploring the possibility of developing a course.

Reasons given in support of technical entrepreneurship courses were:

> Entrepreneurship courses sensitize engineering students to the ingredients that are needed to be a successful entrepreneur. They sow the seeds of entrepreneurial activity and sensitize engineers to the need for other (non-technical) skills and other people with complementary skills to make entrepreneurship successful. (provides a course)
>
> Subject is important. In an era of small business formation, students should be aware that they might start their own business.
>
> Need to produce employers, not just employees, for the economic well-being of the country.
>
> Kids come in from high school thinking General Motors. We need to introduce students to the concept of creating their own jobs and employment. (provides a course)
>
> We should have this type of thing encouraged in our faculty. Just from the economic point of view of our province we should be encouraging engineers to start businesses.
>
> In the current economy, which emphasizes fending for yourself, there is a demand to be able to create your own job.

When asked whether he believed there is a need for a course on technical entrepreneurship, William Lennox of the University of Waterloo said, "Yes, it is like a religion with me." His reaction is the result of observing the success of Don Scott's pioneering technical entrepreneurship course, first taught at Waterloo in 1975. Lennox suggests that engineering faculties should offer seminars for first- or second-year students to whet their appetites for the courses in the third or fourth years.

A minority of engineering deans believed there was no need for courses on technical entrepreneurship. Comments included:

> The business of management is best taught when the students have been exposed to an industrial atmosphere.
>
> When students need to start a business they will find the skills. [Such courses are] difficult to teach.

Quite frankly, it is impossible to put into a four-year program all the courses that are needed or recommended by various groups, organizations, and so forth.

Few of the deans commented on whether they thought students wanted information on technical entrepreneurship. However, at the University of Waterloo, the two entrepreneurship courses presented in the faculty of engineering are oversubscribed and students must be turned away.

Views on how courses in technical entrepreneurship should be presented echoed views on the presentation of courses in technological innovation. For example, the majority of deans of engineering thought that information on technical entrepreneurship should be provided in a single, overview, elective course. (Only two deans thought there should be several in-depth courses on the subject.) In addition, the deans of engineering believed that courses in technical entrepreneurship should be presented by active entrepreneurs, and that a team-teaching approach would be a good compromise when an entrepreneur was not available as a course instructor. Several deans mentioned that it was important for students to meet both successful and unsuccessful entrepreneurs.

Barriers to Presenting Innovation or Entrepreneurship Courses

Far more deans supported the idea of offering innovation or entrepreneurship courses to their students than are actually offering these courses.

The following barriers to offering innovation or entrepreneurship courses were mentioned:

Lack of Money:

Inadequate financial resources to retain outsiders or to free up insiders.

Internal resources are stretched.

It's a matter of priority; it's hard to find money for a new field when you have to cut funds to existing operations.

Scarcity of Competent Instructors:

Main barrier is finding someone excited enough and free enough to teach.

Competing requirements for teaching other material in a time of constant and worsening staff-student ratios.

We need a champion to take it up.

Getting teachers is a real problem. It's preferable to have a dedicated person like Don Scott at the University of Waterloo.

Fitting Into Tight Student Timetables:

Hard to find room in the program; not much elective space left.

Student time is scarce.

Fitting such a course into a heavy student course load.

Trying to fit another course into our programs is, to a certain extent, resisted on the grounds that we are already overloading our students.

Attitude/Reward System of the University:

It [entrepreneurship/innovation] has not appeared as a high priority to teach relative to existing courses.

If we did teach such courses, the university reward system would not give rewards for teaching them.

Peer system would have to be modified to reward a successful teacher. Arts faculty say this area doesn't count.

Such courses are viewed as lacking substance.

Obtaining departmental approval.

One disturbing finding was that many of the deans were not aware of innovation or entrepreneurship courses offered at other institutions in their geographical areas. A few were not even aware of courses offered by the business faculty in their own university. Several were aware, however, that their university's business faculty was overloaded and that it was difficult for an engineering student to take a business course. The need to have taken prerequisite courses, especially for courses in MBA programs, was a major barrier for engineering students. Twelve of the 17 innovation courses offered by Canadian business schools are at the MBA level and are open only to registered MBA students unless special permission is received from the professor.

Comments from Deans of Science

Technological Innovation

Twelve deans of science (Table 1) indicated that they believe that a course on technological innovation should be made available to their science students. A further four stated that the information should be provided in the form of a seminar outside the regular course curriculum. None of the faculties of science have courses on innovation or entrepreneurship. Only the University of Manitoba, in cooperation with its business faculty, had made an effort to establish a course. The course did not attract science students and was discontinued. York University is developing a course on technological innovation for its business faculty and hopes the course will attract science students.

Although they support the need for courses on technological innovation, the deans of science do not appear to be as convinced of the need as do the deans of engineering. Only a few deans provided reasons for supporting technological innovation courses. They remarked that:

Very few students know anything about industry and are not interested in industry. Industry doesn't seem like the natural place to end up. A seminar course would help to educate students and faculty as to what is out there in industry and help bridge the university-industry gap.

The career paths of science graduates may well lead them into managerial positions.

If these students wish to succeed they will require such expertise.

More recently, many scientists are going into industry and are expected to act more like engineers. Students are having to make their own jobs. We need a course that gives people confidence, and the knowledge that the information is out there and they can get it.

Several deans who support having courses commented that they did not think the courses would have wide appeal. Although most of the deans felt that an innovation course should be offered both to graduate and undergraduate students, one dean thought it should be offered only to graduates.

The deans of science who believe that a course or seminar on technological innovation should not be part of a science student's education gave the following reasons for their views:

Curricula too crowded already.

Students too busy with science courses to take innovation courses.

Rather see them go out and get an advanced (MBA) degree later. Subject should be treated seriously and that can't be done in one or two courses.

Several deans of science simply did not see any need for training in technological innovation. As one dean of science stated, "Intuitively it appears important, but I don't know why." This same opinion was expressed 12 years earlier by a different dean of science at the same university.[12]

Deans who supported courses agreed that they should be elective for most science students. Several supporters of seminars felt that this approach was the best way to introduce students and faculty to the topic. As one dean put it, "a seminar type course is the least intrusive and will be more acceptable to science department heads." One dean also supported teaching the innovation process in regular science courses as well as in a dedicated course.

There was general agreement that the instructor for a technological innovation course should come from outside the science faculty. Several deans hoped that an appropriate instructor could be found in the business faculties. They felt that, in addition to being competent in the innovation field, instructors should understand scientists. Team-teaching with guest speakers was considered a possible approach.

Technical Entrepreneurship

The 13 supporters of technical entrepreneurship courses (Table 1) gave the following reasons for their support:

The student should have some appreciation of the problems involved with establishing a high technology firm.

Science students do start their own businesses.

Many students would get a lot out of it.

Several supporters qualified their support by stating that they did not think that their students would be interested in taking an entrepreneurship course. They thought

that a technological innovation course with an R&D element would be more useful. Several deans, however, thought that a technical entrepreneurship course would be of interest to graduate students and faculty.

Those deans of science who were against having courses or seminars on technical entrepreneurship made available to science students put forth the following arguments:

No college can be all things to all people and it is important for us to provide our students with a strong scientific background for their further studies and allow them to develop their career interests.

Single course is inadequate.

The students who need such courses will have no trouble finding them. Business schools everywhere give them year round.

There was general agreement that courses on entrepreneurship should be elective and made available both to graduates and undergraduates. Few deans, however, commented on the need for entrepreneurs to teach the courses, a point considered important by the deans of engineering.

Barriers to Presenting Innovation or Entrepreneurship Courses

Unlike the faculties of engineering, no faculty of science surveyed offers courses on technical entrepreneurship or technological innovation. Most of the engineering faculties have only offered such courses since 1974.

The deans of science were asked what barriers they would face in developing and offering courses or seminars on innovation or entrepreneurship. The main barriers mentioned were:

Faculty Resistance:

Major barrier is faculty indifference or possibly antagonism -- faculty must be educated to understand the need.

Persuading department heads that such courses are important — the need for such courses would have to be sold to each science department.

Need to change the attitudes of faculty towards the commercialization of their ideas and research.

Faculty are very conservative; they would not consider such courses as part of science and would react negatively.

Attitudes of academic colleagues are not supportive of having these courses.

Lack of Resources: Money and People:

No funds available to provide seminars.

Lack of people and resources.

Immense financial burdens prevent us from adding staff.

Faculty opposition to doing anything new because it takes away from their budgets.

Teaching load presents a barrier, assuming there is no new money for such courses.

Do not have the resources or the expertise to offer such courses.

Lack of Interest: Students and Faculty:

Majority of professors would oppose courses because they don't see a need for them.

They are not provided here because staff and students are not motivated by the subject.

I believe such information would be useful, though science students are probably not keen on the subject.

Some faculty would argue for more new science courses rather than innovation courses.

To the question of whether science students want information on technological innovation, P.J. Heald of Memorial University replied:

Whether the students want it or not, I certainly think they need it at this time. Whether and how they will use it is another matter but, from personal experience, I know the value of this type of training in terms of the attitude of mind that it imparts throughout life and in the aid it gives to thinking in relation to the consequences of technological innovation.

In addition two deans speculated that their business faculties might see them as competitors if they developed such courses.

This study found that there had been no change in the availability of innovation or entrepreneurship courses in science faculties since this author's earlier study in 1975.[13] Consequently, some deans of science and engineering were asked why they thought science faculties had not adopted these courses at least to the degree that some engineering faculties had.

The main reason given by the deans of science was that, up to now, they have not perceived any need to include such courses in the education of their students. Moreover, there has been no feedback from employers to indicate any dissatisfaction with the students. Comments provided by the deans are as follows:

Employers have not demanded these skills/knowledge from graduates. No negative feedback from firms.

Until recently, graduates went into academia or government laboratories, but few went into management directly.

No perceived need. Students go on later to get business degrees if they need them. The student clientele that could benefit from the courses is quite small.

Pure science students don't see themselves going into management.

Reward structure and NSERC grants are aimed at those who excel in basic science, not technology applications. Faculty do not see their function as producing a technology or management emphasis to their programs.

Very few professors look at their research with applications in mind, and those that do are looked down on by some colleagues. Attitudes are changing slowly.

Curriculum development is a departmental mandate. Therefore, if science departments are full of people with only pure research and university experience, they put forward courses that reflect their experience.

Engineering faculties are, by nature, applied in their outlook, whereas a large number of science graduates will never be involved in entrepreneurial activities.

Science faculties have an "egotistical" approach to management training. This stuff is so trivial that any real science student who needs it will pick it up when he or she needs it.

Several deans agreed that science professors are simply "cloning" themselves and keeping alive the myth that the students will be doing only research upon graduation. No thought appears to be given to who manages the research.

The deans of engineering felt that science faculties had not adopted innovation or entrepreneurship courses because the reward structure within the scientific community emphasizes pure research and not applications of technology. Some felt that the science faculties were not in touch with the world beyond the campus. The deans of engineering also felt that science professors are also more concerned with their graduate student and honours undergraduate programs. Science faculty do not consider anything to do with the application of technology, including its management, to be important to their own careers, and hence to their students' careers.

Several deans of engineering admitted that an important reason for making courses on innovation and entrepreneurship part of the curriculum for engineering students was that, under the national accreditation rules for engineering programs, at least one-half year of non-technical courses must be part of the engineer's university education.[14] The innovation and entrepreneurship courses fit in this category. As one dean said, "accreditation procedures force engineering faculties to be more responsive to society's needs." There is no equivalent accreditation procedure for science faculties.

Some of the comments by the deans of engineering to account for the lack of innovation or entrepreneurship courses in science faculties were:

Success in a science faculty is to publish in scholarly journals, etc. The reward structure reinforces purity, not application. It is considered that only failed scientists get into applications.

Few in science see that it is their responsibility to deal with industry. Applications of science are considered prostitution.

A scientist's promotion is determined by publication in learned journals, while engineers see themselves as technology transfer agents. Science faculty is more protected from the real world.

Science faculties focus on their graduate programs and are not overly concerned for their undergraduates. Science faculties do not have the same concern about how their students will fit in after graduation.

Science faculties are primarily concerned with honours students. The view is that scientific skill development is paramount.

Technological innovation is less appreciated in terms of reward. The science system is less responsive to society's needs than is engineering.

Science faculties have an ivory-tower approach -- they are out of touch with reality.

Science faculties still think they are oriented to basic science, not applied. They have a purist mindset, although it is changing slowly.

It appears, that between a lack of awareness of any need for such training, and a reward system for university scientists that does not consider either the application of science or the quality of management of research and development to be important, science faculties have been under little pressure to change their approaches to teaching science. The deans of engineering appear to feel that science professors are unaware of the need for training in innovation or entrepreneurship because they are out of touch with reality and, in a sense, living in the past.

Views of Deans of Business

Eight deans of business were contacted to obtain their views on the need for management training in technological innovation for commerce students. Most of the deans agreed that their students were not as aware about technological advances and the technological innovation process as they should be, and that there was room for improvement in the business curriculum. Several deans pointed out, however, that many of their MBA students have engineering or science degrees and therefore appreciate the impact of technological change on businesses and the economy. One of the deans was not aware that a considerable body of information on the management of technological innovation already existed.

Only two deans considered that compulsory courses in technological innovation should be made available to commerce students. One dean commented that such courses are necessary so that when commerce students, "appear on the job, they will be familiar with recent technologies and the direction they are heading." Several deans of business felt they were filling the need for information on technological innovation by means of existing elective courses on technological innovation.

Most deans felt that the topic of technological innovation should be a component of existing courses. Only one dean considered that this was already the case. One of the impediments to including the management of technological innovation in existing courses was seen to be the non-technical background of most business professors.

Most deans felt that they had at least one person on staff who, if interested, could develop a course on either technological innovation or entrepreneurship if requested by engineering or science faculties. They pointed out, however, that current constraints on university budgets would severely inhibit their ability to provide such a course for another faculty. One dean commented, "under the present climate of restraint, we are barely able to meet existing demands from our own students." Even those whose professors are currently providing courses in technological innovation commented that

they could not provide more courses without additional resources. Only one dean felt that he had both the knowledgeable, interested faculty and the resources to provide innovation courses to other faculties.

It appears that lack of funding and knowledgeable, interested faculty discourage business faculties from developing and presenting new or additional technological innovation courses. Business faculties, may not, therefore, be a source of such courses for science and engineering students.

CHAPTER 3
CANADIAN UNIVERSITY COURSES IN TECHNOLOGICAL INNOVATION AND ENTREPRENEURSHIP

Forty-two Canadian universities were contacted to determine whether they had on-going or short courses in technological innovation or technical entrepreneurship in their business, engineering, or science faculties and whether they had centres of study or concentration in either the innovation or entrepreneurship fields. The business faculties were contacted by telephone; the faculties of engineering and science were contacted either by telephone or mail.

On-Going Courses

In the past five years, several universities have developed or have begun to develop engineering management programs. These include the University of Alberta, the University of Ottawa, the Technical University of Nova Scotia, and Simon Fraser University. Others, such as Carleton University, incorporate a single engineering management course in their regular engineering degree programs.

Most of the courses in engineering management programs place little emphasis on the management of technological innovation. They provide the engineering student with information on general business management principles. A typical course is offered by Carleton University's faculty of engineering. The course covers the following topics: history, philosophy, and styles of management; planning, organizing, directing, controlling; personnel management; financial management; project management; matrix/line/staff organizational structure; management tools; problem solving; decision making and rational analysis; information systems and network analysis; collective bargaining; union management; psychology of management; contract management; career planning and job finding.

Some universities, such as McMaster, have combination engineering-MBA programs. These programs enable an engineering student to obtain an MBA degree as well as an engineering degree by taking an extra year of studies. Other universities offer specialized management programs to meet specific engineering needs. For example, the University of Calgary has a project management program with seven core courses on the general theme of managing construction projects.

The distribution of on-going courses on either technological innovation or technical entrepreneurship across Canada is given in Table 2. Single summer courses or courses that have not been presented for the past few years are not included.

Not surprisingly, Ontario and Quebec, the two provinces with the most manufacturing industry, offer the bulk of the innovation and entrepreneurship courses.

Twenty of the 42 Canadian universities surveyed have courses on either technological innovation or technical entrepreneurship. Of these, only the École Polytechnique, Laval, Queen's, Waterloo, and Western have both types of courses. Only eight of the 32 faculties or schools of engineering surveyed have innovation or entrepreneurship courses. They are at Alberta, the École Polytechnique, Laval, Ottawa, Queen's, the Technical University of Nova Scotia, Toronto, and Waterloo. No faculty of science had either type of course.

Table 3 provides a list of 34 courses on the process and management of technological innovation offered at 17 Canadian universities. Several of the courses have not been given in the past six years. Included in this listing are courses that deal

Table 2. Distribution of On-Going Courses Across Canada

	B.C.	Alb.	Sask.	Man.	Ont.	Que.	N.B.	N.S.	P.E.I.	Nfld.
Innovation	0	3	0	1	16	7	0	2	0	1
Entrepreneur-ship	0	4	0	0	6	4	0	0	0	0
	0	7	0	1	22	11	0	2	0	1

Table 3: Canadian Technological Innovation Courses

University	Course Title	Year Set Up	Faculty	Instructor/ Contact
Alberta	Managing in a Technical Environment	1986	Engineering	J. Sprague
Alberta	Engineering and Society	1987	Engineering	J. Whiting
Alberta	Product Management & Product Development[a]	1986	Business	H.C. Young
Calgary	Management of Technological Innovation[b]	1986	Business	P. Abetti[c]
Carleton	Interactions in Industrial Society	1972	Arts	J. Lukasiewicz
Carleton	Technology and Society: Assessment	1981	Arts	P. Kruus
Carleton	Technology and Society: Forecasting	1981	Arts	P. Kruus
Carleton	Technology and Society: Innovation	1984	Arts	W. Gilles
Dalhousie	Managing Technological Innovation and Entrepreneurship	1975	Business	M.J.C. Martin
École Polytechnique	Elements of Industrial Innovation	1980	Engineering	R.A. Blais
École Polytechnique	Technology Forecasting and Development	1986	Engineering	M. Normandin
École Polytechnique	New Product Development	1980	Engineering	M. Zins
École Polytechnique	Technology Transfer	1982	Engineering	J.P. Bonhomme
École Polytechnique	Graduating Essay on an Innovation or Entrepreneurship Project	1980	Engineering	Unknown

(continued on next page)

Table 3: Canadian Technological Innovation Courses (continued)

University	Course Title	Year Set Up	Faculty	Instructor/ Contact
Laval	Introduction to the Management of Technology	1982	Engineering	P.-H. Roy
McMaster	Innovation	1977	Business	P.M. Banting
McMaster	Product Marketing[d]	1985	Business	R.G. Cooper
Manitoba	Issues in Technological Change	1980	Business	M. Bartell
Manitoba	Management of Research and Development[b]	1983	Business	M. Bartell
Memorial	Management of Technological Innovation	1985	Business	M. Skipton
Ottawa	Innovation Policy and Management	1983	Business	A. Albagli
Ottawa	Managing Technological Risk	1984	Business	J.C. Nash
Ottawa	Creativity and Innovation	1982	Engineering	J.A. Doutriaux
Ottawa	Technology Policy and R&D Management	1982	Engineering	Never presented
Ottawa	Industrial and Technology Marketing	1986	Business	R.M. Cuthbert
Québec (à Montréal)	Technology and Innovation	1980	Business	R.E. Miller
Queen's	Management and Technology	1976	Business	P. Richardson
T.U.N.S.	Managing Technological Innovation	1986	Engineering	M.J.C. Martin

Table 3: Canadian Technological Innovation Courses (continued)

University	Course Title	Year Set Up	Faculty	Instructor/ Contact
Waterloo	Technological Innovation and Its Management	1974	Engineering	M. Volker
Waterloo	Patenting for Engineers	1986	Engineering	A.M. Hale
Western	Management of Technology[d]	1970	Business	A.R. Wood
Wilfrid Laurier	Management of New Technology	1984	Business	Hamid Noori
York	Management of Creativity & Technical Innovation[e]	1979	Business	T.E. Clarke
York	Strategic Management of Technology Based Firms	1984	Business	J. Dermer

[a] Previous versions of this course taught in the past but not continously.
[b] Special offering during summer.
[c] Guest lecturer from Rensselaer Polytechnic Institute, Troy, New York.
[d] Graduate and undergraduate versions.
[e] Course not presented after 1980.

with developing new products. Except for the courses presented at Carleton University, the innovation courses are offered by business or engineering faculties.

Table 4 gives a list of 14 courses on technical entrepreneurship at 10 Canadian universities. All these courses are in engineering or business faculties and provide some information on starting a high technology business.

Table 5 shows the timing of the development of the innovation and entrepreneurship courses. Most of the courses have been developed since 1980.

The following comments provide additional information about some of the university programs. Appendices 1 and 2 contain the individual course outlines.

The École Polytechnique de Montréal, as part of its engineering undergraduate program, has the most comprehensive program of courses on innovation and entrepreneurship in Canada. The "Industrial Innovation" option resulted, in part, from the establishment of the Industrial Innovation Centre at the École Polytechnique in 1979. The courses offered by the École are taught by its own faculty and have been developed under the guidance of Roger Blais, former head of the Industrial Innovation Centre at the École. In addition to the six courses now offered, the École is considering introducing a course on creativity. Comments by École students in 1985 and 1986 about one of the courses, "Elements of Industrial Innovation," were very favourable.

The "Entrepreneurship and New Venture Development" program of the faculty of management at the University of Calgary is one of the most successful entrepreneurship programs in Canada; it offers nine courses dealing with entrepreneurship. Established in 1976 under the leadership of Ed McMullan and Wayne Long, this program not only provides courses leading to an MBA in entrepreneurship but also gives advice and assistance to entrepreneurs struggling to develop their businesses. Four of its entrepreneurship courses deal with the specific problems of establishing technology-based firms. Among the program's clientele are scientists trying to develop technology-based firms. In 1986, over 40 per cent of the projects or ventures worked on in the courses involved technology to a considerable degree.

Of the 10 students who received MBAs in entrepreneurship in the first seven years of the program, seven started businesses of their own, and one improved a business. Seven of the eight businesses reported total revenues in 1984 of $16.2 million and employed 87 people.[15]

Science Faculty Involvement in Courses

Only two examples were identified of science faculty being involved in the development or presentation of a technological innovation course. The first example, Carleton University's program in "Technology, Society, and the Environment Studies," is chaired by Peeter Kruus of the science faculty, although it is an arts faculty offering. It includes courses on technology assessment, technological forecasting, and technological innovation. The program was established in 1972 under the direction of Jules Lukasiewicz of the engineering faculty. Courses are open to undergraduate students in all faculties but do not attract many science or engineering students.

The second example, a course at the University of Manitoba entitled "Issues in Technology Change,"[16] was developed as a joint venture between the faculties of administrative studies and science by Marvin Bartell of the faculty of administrative studies. According to Bartell, "this type of course fosters university-industry cooperation and technology transfer. Students interact in the classroom and in the field

Table 4: Canadian Entrepreneurship Courses With Some Emphasis on Establishing Technology-Based Firms

University	Course Title	Year Set Up	Faculty	Instructor
Alberta	Organizational Analysis[a]	1982	Business	Charles Lee
Calgary	New Venture Entrepreneurship[a]	1976	Business	Ed McMullen
Calgary	New Venture Opportunities	1986	Business	Ed McMullen
Calgary	New Venture Marketing	1974[b]	Business	W.A. Long
École Polytechnique	Entrepreneurship and the Study of New Enterprises	1980	Engineering	J.C. Martin
Laval	Process of Entrepreneurship	1985	Business	Yvon Gasse
Québec (Trois-Rivières)	Creativity, Innovation, and Entrepreneurship	1981	Business	J.-A. Julien
Queen's	Market-Oriented Design	1969	Engineering	R. de Pencier
Sherbrooke	The Entrepreneur and the Creation of an Enterprise	1971	Business	J. Robidoux
Toronto	Innovation and Entrepreneurship	1977	Engineering	A.J. Szonyi
Toronto	The Business of Software	1986	Business	R. Baecker
Waterloo	Entrepreneurship for Engineers	1975	Engineering	P.L. Silveston
Waterloo	Technical Entrepreneurship[c]	1984	Engineering	R.H. Grasley
Western	New Enterprise Management[a]	1972	Business	R.M. Knight

[a] Graduate and undergraduate version.
[b] Underwent a major revision in 1984.
[c] Course originally designed and presented in 1979 at York University.

Table 5: Historical Development of Courses

	1969-71	1972-74	1975-77	1978-80	1981-83	1984	1985	1986
Innovation	1	2	3	6	8	4	2	8
Entrepreneur-ship	2	2	3	1	2	1	1	2
	3	4	6	7	10	5	3	10

during their research assignments, with entrepreneurial role models, inventors, and managers of research and development."[17] Bartell strongly endorses the use of local guest lecturers to reinforce the fact that successful innovators and entrepreneurs do exist in Canada. He also believes that one of the benefits of an inter-faculty course is that it enables students from science, engineering, and business to collaborate on various projects.

Students commented that:

> [The course] has made me aware of the benefits of innovation and technology, which I feel will be invaluable to Canada's future.

> I am pleased to find a course aimed at the individual who thinks in terms of becoming an entrepreneur, rather than joining an organization.

Use of Guest Lecturers

In contrast to other courses taught in engineering and business faculties, the courses on technological innovation and technical entrepreneurship made extensive use of outside guest lecturers. Some of the courses had guest lecturers at every session. Only one or two of the courses do not use outside speakers. This use of guest speakers is in line with the expectations of the deans of engineering and science that such courses should involve, as much as possible, practising innovators and entrepreneurs.

Short Courses

Several Canadian universities offer short courses, based on regular university courses, through their extension education departments. Twice a year, the University of Waterloo offers a patenting course entitled, "Protecting your Ideas: Patents, Industrial Design, Copyright, and Trade Marks." This eight-evening lecture course is presented by Alan M. Hale, of the faculty of engineering. The topics covered are: intellectual property; stimulating creative employees; copyright, trade marks, industrial design, trade secrets; inventor's workbook; improving the quality of patents; patent searching; patentability; the patent application; patent claims; infringement; and patent agents. Topics covered in this course are not covered to the same degree in any other courses designed for technical professionals in Canada.

McMaster University offers a two-day course entitled, "New Products: Selecting, Managing and Launching," by Robert G. Cooper of the business faculty. Topics include: generating new product ideas; screening new product ideas; factors in new product success; indentifying the target market; researching the new product market; and planning the launch. Cooper also offers this course under the auspices of the McGill University extension program.

Concordia University offers a one-day executive briefing on the "Strategic Management of R&D: Linking Technical and Business Planning." The course is presented by Eric G. Wiseman, senior consultant of the technology management group of Pugh-Roberts Associates Inc. The briefing covers the technology planning process (the role of technology, corporate technical planning, business-unit technical planning, communicating the business impact of technical effort) key technology-planning issues (technological life cycles, functional competition, business diversification); and R&D allocation (identifying risk in R&D programs, determining the risk/benefit tradeoff in R&D, project selection and termination, allocation of R&D personnel and resources, R&D project portfolio management).

Centres of Expertise

Several universities in Canada have developed or are trying to develop programs that go beyond the establishment of individual courses on technological innovation or technical entrepreneurship. Among the objectives of these various programs is improving the link between the universities and the private sector, and developing a research capability in technological innovation and technical entrepreneurship. A brief overview of what these universities are trying to accomplish is given below. Further details can be obtained directly from the universities.

University of Toronto: The Engineering and Management Centre was established in 1983 under the direction of Andrew J. Szonyi. Its mandate is to:

- provide a closer link between the faculty of applied science and engineering and the faculty of management studies;
- provide more effective service in the area of engineering management to both the University of Toronto and the external community;
- initiate and promote studies and research in the areas of innovation and entrepreneurship;
- foster the exchange of information between the University of Toronto and the industrial and business communities;
- administer the engineering management program (sponsored by the Canadian International Development Agency) at the Huazhong University of Science and Technology in Wuhan, China.

With the help of an advisory board of interested business people, the centre hopes to strengthen linkages between the university and industry.

Queen's University: Canada's first industrial chair in technology and management was established in 1986 at Queen's University. The first appointment to the chair, Mark Abbott, formerly of Polysar Canada, will be cross-appointed in the faculty of applied science and school of business. Funding for this chair, $729 000, is provided by Alcan Aluminum Limited and the Natural Sciences and Engineering Research Council.

University of Western Ontario: The National Centre for Management Research and Development (NCMRD) at Western was established in 1984 to increase productivity of research in the field of management and to solve management problems of national importance.

The NCMRD has two major aims:

- to stimulate, coordinate, and conduct research in the areas of entrepreneurship, productivity, and international business;
- to form a two-way communications link between management practitioners and researchers in the interest of effective dissemination and use of research findings.

One of the research themes for 1986-87 is generating profit from new technology, under the guidance of Roger More.

The centre is funded by grants from the federal government, the university, and private and corporate donors. It is governed by a board of university faculty and representatives of other universities, the business community, and government.

Wilfrid Laurier University: In May 1985, Wilfrid Laurier established the Research Centre for Management of New Technology (REMAT). Under the guidance of Hamid Noori, REMAT has the following objectives:

- to help Canadian managers acquire and implement new technology;
- to provide a forum for industry, governments, and labour to resolve problems related to technology in the workplace;
- to develop practical research programs to improve the capability of Canadian managers to deal with new and emerging technologies.

REMAT is funded by its membership of over 350 small and medium-sized firms.

McMaster University: McMaster University is currently setting up the McMaster Management of Technology Institute. This will be a cooperative industry-university centre focusing on the management of technology. The objectives of the institute will be to:

- provide education in the fields of new product and new process development and other technology management topics;
- undertake research on aspects of the management of technology and innovation;
- act as a national and international link, providing for interchange or transfer of experts, professionals, research, and teaching programs from Canada and abroad.

The institute will be the joint activity of the school of business and the faculty of engineering. Its operating costs, estimated at $1.25 million annually, will come from sponsoring firms, the university, and governments. D.S. Greig, formerly assistant vice-president of Northern Telecom, has recently been appointed interim director of the institute.

CHAPTER 4
VIEWS OF FACULTY WHO TEACH COURSES ON MANAGING TECHNOLOGICAL INNOVATION AND ENTREPRENEURSHIP

Faculty who had developed or presented innovation and entrepreneurship courses were surveyed to determine how they became involved in teaching in this area, and the impact of teaching innovation or entrepreneurship on their careers and on their students. Faculty were also asked to provide students' opinions about their courses (a comprehensive direct survey of students was beyond the resources of this study).

Of the 15 faculty who responded, 13 had developed the course being taught. One professor had taken over an innovation course from a previous instructor, and one professor had turned over teaching of the entrepreneurship course he had developed to other professors after teaching it for several years. In all cases, the courses in both engineering and business faculties resulted from the action of individual faculty, rather than the decisions of a university committee or department head. It is interesting to note that many of the business faculty instructors had engineering or science degrees in addition to business degrees.

Reasons for Developing the Courses

Among the reasons given for becoming involved in such courses were personal interest in, or strong conviction about, the importance of technological innovation or technical entrepreneurship to students. As Roger Blais, of the École Polytechnique, commented:

> I got started in this area because of a personal conviction that an engineering school should facilitate and stimulate innovation and entrepreneurship, and promote creativity. Innovation is the single most important driving force of progress in any society. Engineers must have some knowledge of how technology fits into progress. They need some comprehension of the innovation process, especially the management and marketing aspects.

Other professors gave the following reasons for teaching the courses (the faculty in which the respondent teaches the course is indicated in parentheses):

> My perception of the need for seniors in engineering and science to develop a clear understanding of the technological innovation process, the dynamics of technology-based substitution, and of the modern concepts and techniques used to integrate technology into corporate planning. (engineering)

> Having a PhD in molecular sciences and a MSc in management, I perceive a need to bridge the gap between the technical and the commercial. (business)

> To make students aware that there is an alternative to being an employee. (business and engineering)

> Personal interest and a belief that the topic (innovation and entrepreneurship) provides a good vehicle for introducing engineering students to the key problems and issues in management. (business and engineering)

> Personal interest and student requests. (engineering)

> The realization that innovation is the key to wealth creation and that the protection of intellectual property is an essential part of that process. (engineering)

Requested by business students. (business)

Interested in applied creativity in a business context. (business)

My field is industrial marketing and I wanted to do more with technological innovation. (business)

In a sense, the professors who develop and teach these courses are academic mavericks, following their own convictions that the area is important to their students and that courses should be made available. Their actions were taken with little or no support from their universities or from any outside agencies. The only support for many of the professors was research grants from the Technological Innovation Studies Program of the then Department of Industry, Trade and Commerce. This program, which was terminated in 1985 to cut costs, also provided grants for developing and improving some of the courses.

As one of the engineering faculty stated, "External attitudes do not encourage this kind of teaching or research. In particular, no granting agency is likely to fund engineers or scientists in this sort of work." Another engineering professor stated, "The faculty of science and engineering does not consider technology management as a core discipline and the faculty of business administration does not have the right kind of personnel to support a technology management program." This perception of a lack of capability in business faculties was echoed by one engineering dean when he said, "I would despair of getting people in our business school to teach it [technological innovation]."

Impact of Courses on Careers of Faculty

The course instructors were also asked whether their involvement in teaching innovation or entrepreneurship courses enhanced or hindered their own careers. Many, especially the engineering professors, thought that initially their careers were hindered until their colleagues saw the value of the courses. Even business professors teaching entrepreneurship courses faced some antagonism at first. The following comments illustrate some of the problems:

I avoid the use of terms "innovation" or "entrepreneurship" so have no problems.

I acknowledge that it is difficult if one's interests do not fit within currently accepted academic boundaries. I put myself in the policy area for purposes of academic classification.

In the absence of formal support from the university, and if I were beginning my career, I would certainly feel hindered.

[My career is] enhanced now.

Too early to tell but, within my engineering field, probably hindered.

There is some internal recognition, but not much.

My engineering career has been hindered.

I understand that even as recently as three years ago, entrepreneurship courses were the butt of some humour at a university level committee. Things have changed since, however.

During a November 1986 conference on entrepreneurship held in St. John's, Newfoundland one of the authors noted that many of the entrepreneurship instructors complained that they did not receive much respect from their colleagues for their teaching activities.

Impact on Students

The professors consider that the major benefits to students of attending innovation or entrepreneurship courses are:

- a new awareness of entrepreneurship as a career option;
- a better understanding of management;
- a broad perception of the role of technology in industrial development;
- an understanding that technological innovation involves the integration of many disciplines, technical and non-technical;
- a better understanding of what to do if they have a technical idea that has commercial potential;
- better developed decision-making skills.

Most of the professors used guest speakers from industry or government. One of those who did not used video tapes of entrepreneurs describing their experiences.

Many of the professors believed that meeting practising innovators and entrepreneurs was an important benefit for students. They felt that the students received encouragement from the guest lecturers and, in the case of entrepreneurial guest speakers, a feeling of "If they can do it so can I."

One of the earliest courses on technological entrepreneurship for engineering students was developed and presented by Don Scott, of the chemical engineering department of the University of Waterloo. Scott's reaction to the students in his first class in 1975 is significant. He stated in a review article about his course, "Never in my teaching career have I encountered such a group of interested and highly motivated students."[18] One of the authors can confirm this enthusiasm by personal observation. During a visit to Waterloo in 1978, Tom Clarke asked Don Scott if he could sit in on one of the lectures that was to be held that afternoon. Scott agreed, but that morning Waterloo was hit by a major snow storm and the university was closed at noon. When Clarke mentioned his disappointment in missing the class, Scott smiled and said that the class was still on and he expected the students to turn up. Upon entering the classroom it was clear that his prediction was completely accurate. The room was crowded and the lecture, by a guest speaker on the topic of patenting, proceeded.

During the summer of 1983, Marvin Bartell presented a course at the University of Manitoba on the "Management of Research and Development," which attracted a mix of working R&D managers and undergraduate business students.

Student comments were:

The mix of students and industry is good, again allowing flexibility in discussion.

I feel that the course has been very useful as it ties together the need for research and development and high technology with the management of such projects.

The mixture of students and businesspeople also gave me an insight into the viewpoints and problems in the workplace and some of the ways to solve these problems.

This was an enjoyable and informative course. I thought the case method brought out many good ideas.

Unfortunately, because of lack of resources, this course has not been presented again.

Two students of Paul Roy, of Laval University's engineering faculty, made the following comments in an article about his technological innovation course:

> This course has an exceptional impact on the education of students. It completely changes the student's perception of the industrial world. For example, by improving his knowledge of the process of technological innovation, the student is able to grasp the role and orientation to give to research and development within the business world. One interesting aspect of this course is the opportunity it offers students to meet key people from industry, government and university. Science and engineering graduates tend to be apprehensive about entering the industrial world. This course makes it much easier for the young graduate to adapt to the industrial environment.[19]

A comprehensive survey of former innovation or entrepreneurship students was beyond the scope of this study. However, as part of another project one of the authors, Jean Reavley, has collected the views of former engineering students of Robert de Pencier's course on market oriented design (MECH 492/493) and Andrew Szonyi's and J.C. Paradi's course on innovation and entrepreneurship (CHE 557S). The following are students' comments about the courses and their answers to a question about whether the course(s) had had an impact on their subsequent careers:

Market Oriented Design (Queen's University)

> Yes, I am now starting my own business as a technical entrepreneur after 3 1/2 years with a large organization.
>
> The course has reinforced my desire to start a small design firm in 1987.
>
> It planted the entrepreneurial seed.
>
> In my four years at Queen's, these two courses were the most satisfying.
>
> The course at Queen's was grossly underestimated by the faculty of applied science. As far as I am concerned Dr de Pencier should be given a much larger budget to run the program.

Innovation and Entrepreneurship (University of Toronto)

> It helped me to understand the requirements of starting up a new company.
>
> I became more business oriented; accepted employment in a scientific business position rather than a technical position.
>
> The course, as taught, was an invaluable one, given the restrictions of time. It sensitizes the potential entrepreneur and, I believe, fundamentally changes his or her perspective of the business community.

I work for a start-up firm in a highly technical product area. I thought the course was excellent.

Yes, definitely; it made me want to pursue an entrepreneurial path, after gaining experience in business working for someone else. The course is an excellent one. The involvement of industry guest speakers is a great asset.

The only professor who mentioned that he had PhD students studying in the area of technological innovation was Roger E. Miller, at the University of Quebec at Montreal. One student is studying the burn-out phenomenon in scientists and engineers, and the other is studying early technology centres.

CHAPTER 5
IS THERE A NEED FOR TECHNOLOGICAL INNOVATION/ENTREPRENEURSHIP COURSES FOR SCIENCE AND ENGINEERING STUDENTS?

> Scientific men are usually indifferent administrators and seldom men of the world. They should not be expected to undertake tasks for which their expertise and training have not fitted them. It is wasteful to turn a first-class scientist into a second-rate administrator. Administration is a job for people who have been trained to administrate, but if they are to administrate scientific activities they must have had a broad general scientific education. I cannot see that this is impossible, though I admit it is a long-term policy.
>
> Sir Henry Tizard[20]

This chapter is based on a review of studies of the quality of the management of science and technology, and general business management in Canada; of the views of technical managers on the need for management training; and on the adequacy of university education in the area of innovation and entrepreneurship.

Quality of Management in Canada

In general, Canadian managers do not rate as well as their counterparts in other countries. When the Geneva-based European Management Forum rated the international competitiveness of 22 Western industrial countries in 1985, Canada came 7th overall, but was rated 15th in overall "innovative forward orientation," which is a measure of future-oriented investment, R&D, and patents.

In particular, Canadian managers rated:

- 7th for managerial readiness to delegate;
- 12th for ability to exploit inventions commercially;
- 13th for managerial drive and entrepreneurship;
- 22nd for encouraging worker participation in management.

Thus by international standards, Canadian businesspeople have considerable room for improvement.

Lack of Managerial Skills

Several recent studies of technically trained people have noted deficiencies in managerial skill. Rush and Evers, for example, found that Canadian science and engineering graduates felt deficient in written and oral communication, leadership, and administration skills.[21] Some of the graduates interviewed by Rush and Evers commented:

> Being in a science stream, there is very little oral or written communication beyond numbers. You also work alone most of the time — this develops initiative, problem solving, but does nothing for team work, interpersonal skills, etc.[22]
>
> Administrative skills, time management and general management skills were not dealt with adequately even though I was in an engineering and management course.[23]

Rush and Evers also found that the level of job satisfaction experienced by a new graduate was to some degree determined by "the number of days of non-technical training received. The more non-technical training received by graduates, the more they are satisfied with their jobs."[24]

Previous observations by the authors and comments made by some of the deans surveyed during this study show that many technically trained professionals, especially scientists, do not believe there is anything to learn about the management of technological innovation or entrepreneurship. They believe effective management is just common sense, or that it is easy to pick up as they go along.

Many studies show, however, that scientists and engineers do not easily acquire necessary managerial skills as they put their technical skills into practice. Scientists and engineers also do not appear to think it is important to hire personnel who have the management training needed to compensate for their own deficiencies.

Russell M. Knight, after extensive studies of technically oriented entrepreneurs in Canada, believes that many do not possess the general management skills (especially in finance, manufacturing, and marketing) necessary to launch new Canadian innovations efficiently.[25] In a survey of 124 small high technology firms, he found that 24 per cent of the founders had science degrees and 43 per cent had engineering degrees. Only 16 per cent had business degrees. He also found that, "the founders usually brought in people who were similar in background and interests to themselves, other technically oriented people, rather than trying to complement their weaknesses by hiring people skilled in the general management areas."

Knight concluded that most of these new technology-based firms should be made aware of their lack of managerial capability and actively recruit people who have financial and marketing skills. He further concluded that:

> It is a sad fact that many of the high technology firms and the entrepreneurs in them never quite recognize the need for these general management attributes. In fact, it is probably a basic problem that these highly technically trained people do not interact well with general management types of individuals and cannot see the need for them. They tend to be overconfident in their own general management skills, even when they have had no previous training or experience in the area.[26]

Knight suggests that management training would help these technical entrepreneurs, but notes that, "these individuals are not very favourably oriented towards more training, especially when they do not recognize the need for this general management skill."

The aversion to management training was also noted by Richard McBride in a study of the career paths of biologists in Canadian government and university laboratories.[27] Although the scientists admitted to needing additional skills in financial management, project management, and personnel management, they expressed little interest in obtaining them through management training. McBride notes, "The lack of appreciation for management as a formal body of knowledge requiring the same professional dedication as the science specialties was striking." He concludes that, "Researchers in the natural sciences are sceptical about the value of the social and administrative sciences. They seem to think that skills in management are innate, intuitive, or best learned on the job."[28] What is noteworthy about McBride's comments is that he is not a management professor with a bias toward promoting management courses, but a biology professor concerned about the career paths of his science students.

This naive and crippling attitude toward management knowledge and skills has also been noted by one of the authors while teaching R&D management courses to scientists and engineers. On the first day of a course, it is quite common for a class to argue that R&D management is just common sense and that there is no need for any management

training. Fortunately, by the end of a course, most students have changed their minds and recognize that there is a body of knowledge that an R&D manager must acquire in order to be personally productive and also to lead a productive research team. This experience suggests that it should be possible to prevent scientists and engineers from developing a self-defeating attitude toward the management of technological innovation and technical entrepreneurship by exposing them to appropriate courses while at university.

Doutriaux and Peterman in a study of academic entrepreneurship noted that academic entrepreneurs tend to disregard the need to bring people with business experience into a company.[29] This blindspot occurs because nothing in their university education makes them aware of the factors that increase the probability of a successful innovation.

A recent study of innovation activities in western Canada found that, although the educational level of Canadian entrepreneurs was generally high, a significant number were insufficiently trained in the financial, managerial and marketing aspects of business.[30] A dean of engineering who was formerly an employee of a provincial government also considers the skills of managers of small firms to be inadequate. He states, "While working with the provincial government, I was appalled at the number of small companies starting up with little or no knowledge of technology and entrepreneurship. In particular, there was a lack of knowledge of business planning, business organization and management, marketing and business finance. There is certainly a need for training courses -- no doubt about it." This dean, however, is not sure that "university faculties of science and engineering are the place for it," because of existing course loads.

The lack of business skills in technically trained professionals has also been identified outside Canada. In a review of engineering education in the United Kingdom, Beuret and Webb noted that engineers were deficient in management skills, communication skills, knowledge of the business context within which they work, and decision-making skills. One respondent in the review considered that an engineer's lack of business awareness was, "ignorance fueled by reluctance."[31] The Finniston inquiry in Great Britain "received a substantial volume of evidence both from educationalists and employers concerning the generally poor communicative skill...of many engineers and engineering students, and their narrowness of outlook."[32]

Views of Canadian Managers

Several studies have shown that managers of technology-based organizations require skill in operating within organizational structures, and that technical training alone is not sufficient. In an address to the Special 75th Anniversary Convocation of the University of Saskatchewan, John Stoik, former president and chief executive officer of Gulf Canada Limited, stated that, "Rather than being able to stay comfortably within a familiar, vertical niche, people are going to be expected to think and act horizontally across the old, vertical, organizational lines."[33] This will require training in skill areas beyond the strict boundaries of a technical discipline.

Rush and Evers found that 66.7 per cent of the managers they surveyed believed that technical training should be modified to allow more general or liberal arts courses to be included in degree requirements. An additional 11.1 per cent agreed with this view, providing there was no compromise in technical training.[34] Some of the managers commented:

> Yes, provided that you don't compromise on technical concepts. For technical people, training on how to sell themselves, make presentations, deal with wage people and professionals in conflict situations etc. would definitely benefit them.
>
> Specialized technical training becomes obsolete very quickly due to the current rapid advancement of technology, therefore education at the bachelor's level should concentrate on basic problem solving methods and management techniques, together with oral and written communication skills.[35]

When asked about the problems they experienced when making the transition from student to employee, managers made the following comments:

> The transition was most difficult in the shift from technical-quantitative-analytical thinking to interpersonal-political thinking. Success and satisfaction are far less dependent on technical ability than I thought.[36]
>
> The difficulties took place later as technical success led to advancement into management positions, with little preparation.[37]

Numerous studies of scientists and engineers in organizations have shown that the transition from the bench to a supervisory position can be difficult for many technically trained people because they usually do not understand the role of an effective R&D manager, the many activities that make up that role, and how to get things accomplished efficiently within organizational rules and regulations.[38, 39]

In a review of the need for innovation and entrepreneurship training in Canadian universities, the report of the T.I.M.E. (technological innovation management education) for Canada Workshop concluded:

> Courses on the management of technological innovation and technical entrepreneurship should be made available to science, engineering, and business students. Many students want such training and small high technology businesses would like the university students they hire to have some awareness of the elements which make up their world of business.[40]

David Vice, president of Northern Telecom Canada Ltd., has made the following remarks concerning the quality of management of high technology firms in Canada and the role of the universities in providing management training:

> We need better managers and we need managers who are better equipped to manage technology as a competitive force....Today we need more engineering in management, and more management in engineering, if our companies are to tap the new technologies to full potential....Plainly and simply, we need the deans of business and the deans of engineering talking together, and with business, about the new knowledge and skills needed to manage in a high-tech age.[41]

Inadequate University Training for Scientists and Engineers

A number of people believe that universities are not preparing their students for the environment they will face when they leave university. In their study of entrepreneurship in universities, Doutriaux and Peterman noted, "most of the professors hired in the last 10 to 20 years have no industrial experience and most of them do not know what the real world looks like."[42] They suggest that the more practically oriented engineering talent is going to industry, leaving universities to hire more theoretically oriented professionals. This point of view was echoed by a dean of

engineering at a major Canadian university during a conversation with one of the authors several years ago. He stated that if any of his professors were blindfolded and taken on a trip to a local firm that made use of the engineering technology the professor taught, the professor would be unable to recognize the application when the blindfold was removed.

In a study of the attitudes of 150 Canadian industry officials and university academics toward technological innovation training, 61 per cent agreed with the statement that, "scientific and technical university graduates in Canada are not being adequately prepared for employment in industry."[43] Moreover, a recent study of innovation activities in Canada noted the lack of management orientation to science and engineering education despite there being a strong need to increase competence in the managerial dimensions of technological innovation.[44] The study determined that, with few exceptions, the academic environment is not oriented toward industry or business and, in particular, ignores innovation and entrepreneurship. To overcome these deficiencies, the study's authors recommended a systematic integration of management programs into technical and engineering courses throughout the whole education system, including the community colleges.

Several authors concerned with university education have argued that professional success lies in the ability to apply both technical and managerial skills to a job. In an article describing a combined engineering and management course in the United Kingdom, Skipton and Augarde[45] argue that the "management of technological innovation must be essential learning for all engineering students" so that they can work effectively with business professionals. These authors consider that this also applies to science students heading for employment in industry.

Olinga Ta'eed, in a review of science and engineering education in the United Kingdom, states:

> Researchers must comprehend at least the rudiments of organizational systems and associated investment decisions, if they wish to see their work successfully travail the perilous journey through development, implementation and operation.[46]

Ta'eed further argues that the training of PhD students should be modified to make it more relevant to their vocations. He states that:

> Without the contribution of the education system in developing the attitudes and skill which make up Britain's technological research capability, the economic recovery of our industries will be increasingly contingent on our innovative serendipity.[47]

Numerous studies have suggested that entrepreneurship might be a solution to unemployment, especially among the young. A recent study of innovation activities in Canada made the point that trends in employment, particularly the reduction of job opportunities in conventional industry, mean that young Canadians need to be familiar with the new technologies and with the challenge of self-employment that can lead to the development of small firms.[48]

This view that technical entrepreneurship is a possible solution to unemployment among young people is shared by many countries in Europe. The Basque Autonomy Government in Spain, for example, has undertaken a major study of entrepreneurial training in North America and Europe in order to set up a mechanism to assist their

unemployed university graduates to start businesses. They are particularly interested in industrial innovation centres and centres of entrepreneurship.

Some Canadians suggest that Canada's future depends in part on having technical professionals who are equally skilled in technology and management. Rush and Evers in their study of university education and the needs of Canadian industry, concluded that, "a technologically advanced nation such as Canada needs specialists in engineering, computer science, etc.; however, these graduates also need general skills to function in corporations."[49]

In a review of the development of his technical entrepreneurship course for engineering students, Robert de Pencier of Queen's University gives the following reasons for the need to develop entrepreneurial and innovative skills in Canadian engineers:

> Most efforts in our schools of engineering are directed at developing "leading edge", "advanced", "knowledge intensive" mathematically oriented, quantitative skills. If graduating Canadian engineers wish to use their "leading edge" skills, in Canada, they usually must gravitate to large companies which are frequently controlled elsewhere. If they wish to work for smaller, Canadian-owned companies, they frequently find themselves in a situation in which their skills are underutilized or irrelevant.
>
> This course (MECH 492/493) aims at presenting approaches by which an engineer can direct his engineering skills at the problems of Canadian society rather than simply solving "engineering problems" presented and stated by others, often through a hierarchy which does not have its apex in Canada. Inherent also in this course are considerations of qualitative aspects of complex situations and qualities of perception and judgement, in contrast to the quantitative approach to engineering problems which can substitute for judgement and decision.[50]

De Pencier believes that his course "espouses the idea that the Canadian nation would be better served if a technologically trained person pulls together the means to meet the needs of Canadians (the need for employment in industries located in Canada) and of potential customers."[51]

Adequacy of Business Education

This study has focused on the need for courses in technological innovation and technical entrepreneurship for science and engineering students. However, it is also important to note that graduates of university business faculties need to be aware of the role that science and technology plays in economic performance so that, as managers, they consider technological innovation as an important element when making decisions. As Northern Telecom's president, David Vice has stated, "I do expect every new graduate from the business schools of this country to have more technical literacy than how to run a computer."[52]

In their review of technology diffusion in Ontario, Philip A. Lapp Limited recommended that the Ontario government and their technology centres "develop curricula for innovation courses geared to the needs of managers, and focused on how to manage technical innovation and develop corporate innovation models and programs. The purpose of the courses is to make available to managers throughout Ontario, the requisite skills, attitudes, and knowledge for adopting technical innovation their firms."[53] Concern about the narrowness of business education was also noted by Rush and Evers.[54] They found that business students felt deficient in the area of creativity

and innovation as well as in the areas of administration, oral communication, and leadership.

A recent study of MBA graduates by Lynne Hall found that both the graduates and employers were dissatisfied with the graduates' communication and people skills.[55] The study also found that the MBA graduates did not understand the role of technology in business decisions or the technological innovation process. Hall noted that the business deans who responded to her survey did not recognize this shortcoming to the same degree as did the graduates or their employers.[56]

Concern about the quality of management education and whether it is meeting the needs of industry is not confined to Canada. In the United States, for example, the Business-Higher Education Forum, having examined business schools there, recommended broadening managerial training to include the political, environmental, ethical, and technological contexts in which managerial skills are applied.[57] In Australia, a review of technology management education by John Crisp notes the almost complete lack of emphasis on the management of technological innovation in Australian business schools.[58] While, in Britain, a nine-month inquiry was set up in 1986 to look at the appropriateness of undergraduate and graduate management education in Britain. The study, which is funded by the Department of Education and Science, the Department of Trade and Industry, and British industry, is being carried out jointly by the British Institute of Management and the Confederation of British Industry.[59] This activity suggests that business schools in many countries could improve their programs especially in the areas of interpersonal skills development and knowledge about technological innovation.

CHAPTER 6
DISCUSSION AND RECOMMENDATIONS

Courses on technological innovation or technical entrepreneurship provide many benefits for the economy and for the students who take them. However, several obstacles will have to be overcome to improve existing courses, to establish new courses in science and engineering faculties, and to create centres of expertise in technological innovation and entrepreneurship.

Benefits to the Economy

The efficiency and effectiveness of any organization is, to a considerable extent, determined by the quality of its management. If an organization has competent managers, it will be able to take advantage of economic opportunities and will not be caught off guard by either a competitor's actions or sudden shifts in the economy. Poor managers, however, will lead their organizations into difficulty even in good economic times.

The high technology sector is a small but increasingly important segment of the Canadian business community. Growth in the sector is needed to overcome the huge trade imbalance in high technology products and services that Canada is experiencing. To survive, Canadian high technology companies must enter international markets where they face intense competition. Such companies need managers who are every bit as capable as their highly qualified foreign counterparts.

One way to strengthen managerial knowledge and skills in Canadian technology-based firms is to provide suitable training in technological innovation and its management to science, engineering, and business students while they are still in university. Such training, especially for science and engineering students, can lead to the establishment and growth of more technology-based companies.

Benefits to Science and Engineering Students

The main reason why science and engineering students should take courses on technological innovation or technical entrepreneurship is to increase their ability to put their technical skills and knowledge to maximum use as either an employee or an employer.

Research and development is no longer an individual activity but one carried out within the context of an organization. A university course on technological innovation or technical entrepreneurship can equip the graduate with the knowledge to survive within a managed and sometimes hostile organizational environment, and to obtain the resources and assistance necessary to accomplish technical objectives. Furthermore, the courses help sensitize graduates to the fact that managerial skills are necessary to commercialize science and technology successfully, and that they should hire expert assistance if they do not possess the skills themselves.

Technological innovation or technical entrepreneurship courses can alert science and engineering students to the differences between the management of technological innovation and entrepreneurship, and general business management. Graduates who decide on further managerial education, and are going to be closely connected with technological innovation, can then be more selective in their choice of business school. For example, they can opt for schools that provide management training specific to the innovation process rather than those that provide a less useful general business program.

Courses or seminars on innovation or entrepreneurship provide a link with the realities of the outside world. They could also provide a means of bringing industry and government closer to the universities. For example, guest speakers from industry or government could provide information on the problems and challenges facing innovators and entrepreneurs in Canada and provide alternative role models for the students. The value of an entrepreneurial role model for science students should not be underestimated. R.M. Knight has found that 24 per cent of Canadian technical entrepreneurs have science degrees.[60]

Course Location

Technological innovation or technical entrepreneurship courses must be offered by science and engineering faculties if students in these faculties are to take these courses seriously and to gain the benefits outlined above. It is important that the students regard knowledge of technological innovation and R&D management as an intrinsic part of their education. Courses offered by other faculties, including business faculties, are not regarded as being as important or as having the same value as courses in the student's own faculty.

Courses located in science or engineering faculties can also provide encouragement and assistance to students who might be trying to commercialize a technical idea or start a technology-based company. In their review of academic entrepreneurship in Canadian universities, Doutriaux and Peterman found that of the approximately 100 academic entrepreneurs in their sample, roughly one-third had started their companies while either students or new graduates.[61]

Innovation or entrepreneurship course instructors from engineering or science faculties provide powerful role models for students. There are often mavericks in science and engineering faculties who are interested in the commercialization of science and technology, and some even start their own companies. If these professors are available, they should be encouraged to develop and present innovation and entrepreneurship courses.

If business school professors are brought in to give the courses, they should understand the traditions and culture of science and engineering, and should, ideally, have a science or engineering degree. Business professors, however, do not usually provide good role models for technical entrepreneurship. In their study of university faculty entrepreneurship, Vesper and Crosswhite found that "most of the 'hi-tech' firms were started by engineering professors and most of the 'lo-tech' firms were started by business professors." They concluded that, "in general, business professors are unlikely to be involved in startup companies involving advanced or fast moving technologies."[62]

Finally, Robert Ronstadt of Babson College points out that "there is no logical reason to assume entrepreneurial education should be made to fit within the existing structure of an undergraduate or graduate school of management."[63]

RECOMMENDATION 1

Engineering and science faculties should be encouraged to develop and present specialized technological innovation and technical entrepreneurship courses within their own faculties, and to make use of expertise from their own and other faculties, and from the business community.

Facilitating the Spread and Improvement of Technological Innovation and Technical Entrepreneurship Courses

This is at least the fourth study or workshop that has looked at the management of technology in Canada and has concluded that there should be more training in the management of R&D and technological innovation within science and engineering faculties in Canadian universities. Although some engineering faculties have established such courses, none is currently offered by science faculties.

Funding

A problem common both to the spread and improvement of technological innovation or technical entrepreneurship courses is the lack of adequate funding for nontechnical courses in science and engineering faculties. This results in an inability either to hire a suitable person to develop and conduct courses or to encourage an existing faculty member to move into the field. As one engineering dean stated, "Twelve years ago we had the money but didn't care about teaching innovation or entrepreneurship; today we care but have no money." An attempt to establish an innovation course as a joint activity of the engineering and the business faculty at the University of Alberta in 1981 failed because of the lack of a qualified instructor.

One of the major obstacles facing the establishment of nontechnical courses is that they are frequently regarded as mere add-ons -- to be offered only if funds are available. If faculties really believed in the importance of such courses, they would probably be able to find funding for these courses by re-allocating existing faculty budgets. As Ta'eed notes with reference to science and engineering education in the United Kingdom, "Money and prestige is vested in academic departments which in general show an unwillingness to stake precious resources in new and untested areas beyond their exclusively disciplinary boundaries. The problem of resource allocation, however, may not be as an effective barrier as intellectual inertia, indifference, fear, and psychosociological factors."[64]

Several course instructors commented that they received little support in the beginning for the development of technological innovation or technical entrepreneurship courses. With shrinking university budgets, new professors who want to develop and present courses will receive even less support. Even existing innovation or entrepreneurship courses are being threatened as budgets become tighter and there is more pressure to stick to traditional technical or business courses.

Before 1985, the Technological Innovation Studies Program (TISP) of the Department of Regional Industrial Expansion (DRIE) offered grants to university professors to conduct research or develop courses in the areas of technological innovation or technical entrepreneurship. In addition, this program offered scholarships at the masters and doctoral levels to support the training or retraining of new professors or managers. The program could have, for example, taken a science or engineering professor and supported his or her studies in the one-year master of science in the management of technology program at the Massachusetts Institute of Technology. TISP had the potential, therefore, to help overcome the severe shortage of qualified instructors in Canada. Unfortunately, TISP, which had a budget of approximately $200 000 per year, was cancelled in November 1985 as part of general budget cuts in DRIE. Since then Canada has had no dedicated program of support for studies or training in the technological innovation or technical entrepreneurship fields. This gap has not been filled by any of the existing granting councils.

RECOMMENDATION 2

A program such as the Technological Innovation Studies Program should be established to provide funds for research and course development, and to support graduate-level students.

RECOMMENDATION 3

Provincial governments interested in promoting technological innovation and technical entrepreneurship should allocate additional funds to faculties of business, engineering, and science for hiring new professors; for developing, promoting, and presenting courses and graduate level programs on innovation and entrepreneurship; and for student scholarships.

Other Obstacles to the Spread of Courses

Faculty Attitudes: One of the major reasons given by the deans of science for the lack of courses on either technological innovation or technical entrepreneurship was the negative attitude that science faculty and most students would have toward them. The deans claim that there have been no complaints about the breadth of education that science faculties have been providing. The apparent lack of complaints could be because employers are not providing feedback on the need for new employees to have some understanding of the technological innovation process, or because feedback is not reaching or being understood by department heads in science faculties.

Given the poor quality of Canadian managers, as reported by numerous studies, and the lack of innovative firms in Canada, it is not surprising that most managers do not demand that the science, engineering, and business graduates that they hire understand the innovation process and its management. Poor managers are unlikely to want employees with more managerial knowledge than themselves. As some of the studies referred to in chapter 5 point out, many managers in technology-based companies do not see any need for formal training in technological innovation or technical entrepreneurship.

A vicious circle thus develops as inadequately trained technology managers hire narrowly trained scientists and engineers with no awareness of the complexities of the innovation process and its effective management. The latter because of their lack of interest in obtaining formal training in management eventually become ineffective managers, and the cycle begins again.

The few managers who are asking for changes in the science and engineering curricula are not getting their message to the department heads who determine the course offerings. With few exceptions, such as the Montreal-based Corporate-Higher Education Forum, there are no mechanisms whereby industrial managers can communicate with science and engineering faculties. Only one dean of science at a western Canadian university mentioned reading the recent study by Rush and Evers of Canada's university graduates and corporate employers.[65] The dean was concerned about the skill deficiencies identified in science students and was looking for ways to overcome these shortcomings. Only the dean of science at the University of Toronto mentioned having recently set up a industry-faculty liaison committee so that his department heads could meet with industry leaders to learn of industrial requirements in science education.

To facilitate communication, more science departments should set up university-industry liaison committees so that industry can provide science faculties

with a better understanding of their needs, and science faculties can, in turn, keep industry abreast of some of their problems, such as trying to do research with outdated equipment. The recent announcement by the federal government that it will match industrial funds for university research through the three granting councils may be an additional reason for science, as well as engineering and business faculties, to set up liaison committees.

RECOMMENDATION 4

Deans of science should be encouraged to establish liaison committees with industry and government employers to receive feedback on the quality and breadth of the science education provided and to keep industry and government advised of problems that hinder their efforts to provide a first-class education.

Faculty Influence on Students: It is understandable that university students, and especially science students, do not see any need for innovation or entrepreneurship courses because the only role models they have are university academics. Many science professors maintain the illusion that only university research is worthwhile and that any interaction with industry or with the commercialization of science is a prostitution of their talents.

In their efforts to "clone" themselves, many science professors try to instill the attitude that only science is important, and that any other area of study is trivial. The scientists' lack of knowledge of technological innovation and its management is nothing less than ignorance fueled by arrogance.

Through their summer employment, some students may recognize the need to learn more about working in a managed R&D environment. However, if these students ask to take a business course as part of their science or engineering degrees, they could have the same experience as one of the authors who, as a graduate physics student, encountered a closed-minded professor who stated emphatically, "science students do not take business courses."

These attitudes lead to a situation in which, as one dean of science described it, "Our science graduates and undergraduates are very ignorant about the management side of society and the innovation process."

Several deans of science said that science students interested in management could take an MBA later if they felt the need. Unfortunately, most PhDs in science do not see any need for management training partly because their training is directed solely toward a career in research, and partly because of the negative bias toward technological innovation and R&D management that science faculties transmit to students. Many science graduates are even biased against short courses on R&D or innovation management. One senior manager with a major government laboratory responded to the suggestion that he take a short management training course by saying, "Management training? Why do I need management training? I have a PhD in physics." Another senior manager in an east coast laboratory, on learning that some of his scientists were reading books on R&D management from their organization's library, said that his staff were wasting their time and should be reading technical literature instead.

Student Attitudes: Where courses on technological innovation and entrepreneurship are offered by engineering faculties, the response by students has been positive. However, many deans in faculties that did not offer these courses felt that students probably

would not want them. A major problem is that both science and engineering students lack information about the tasks they will have to perform upon joining the workforce and may feel that courses on R&D and innovation management or entrepreneurship are a waste of time. Many students believe that their jobs should be purely technical. New science and engineering employees, however, could be supervising technicians from their first day on the job, or be spending only 60 to 70 per cent of their time on technical activities and the remainder on administrative duties. Most students and faculty are unaware that studies show that the most productive scientists are those who do not spend all their time on technical activities.

As a first step in overcoming this ignorance, a seminar series should be developed outlining students' future work roles, work environment, and career options after graduation. Seminars involving guest speakers who can describe what really takes place in a government or industry laboratory could whet the appetite of students for courses in the management of technological innovation and technical entrepreneurship.

RECOMMENDATION 5

The provincial governments in cooperation with industry associations, such as the Canadian Advanced Technology Association, should sponsor the development and presentation of a series of seminars for science and engineering students to make them aware of the work roles awaiting them after graduation and the option of starting their own companies.

Course Load: Many deans of science and engineering, including those who supported the concept of innovation or entrepreneurship courses in their faculties, worried about the course load on students. However, accreditation rules require undergraduates in engineering faculties to take at least three credits (three full or six half courses) of nontechnical studies.[66] New innovation or entrepreneurship courses would compete for students with existing nontechnical courses and the decision to take them would rest with the students.

There are no formal provisions for nontechnical courses in honours science programs. If there is not enough time in the curriculum to add courses on technological innovation or technical entrepreneurship, consideration should be given to increasing the length of the undergraduate honours program by at least half a year to enable the students to add nontechnical and additional technical courses to their programs. It may now be unreasonable to expect a science student to learn all he or she needs to know in just four years.

At the graduate level students tend to have some flexibility in their programs and could fit an innovation or entrepreneurship course in with relative ease, assuming no faculty restrictions.

Lack of Networking among Faculty: During the progress of this study it was clear that there was little or no communication among course instructors, even when they were on the same campus. Instructors should be encouraged to communicate and, in particular, to share information about Canadian case studies on innovation and entrepreneurship.

RECOMMENDATION 6

Federal government departments and agencies concerned with encouraging and supporting technological innovation or technical entrepreneurship should sponsor a workshop to bring together Canadian business and engineering instructors, and

deans of science and engineering who are interested in establishing courses or seminars so that they can become acquainted with each other's activities, and determine how technological innovation and technical entrepreneurship courses can be made available to more students.

Improving Existing Courses and Research

Inadequacy of Existing Courses: It can be seen from the outlines for existing Canadian technological innovation and entrepreneurship courses in appendices 1 and 2 that instructors are trying to provide their students with as broad an overview of the subject as possible. Most of the courses, however, do not place sufficient emphasis on the human relations and interpersonal skills aspects of innovation or entrepreneurship -- the areas in which innovators or entrepreneurs, especially those with technical backgrounds, fail as managers.

Existing technological innovation or entrepreneurship courses in business faculties do not provide sufficient training in organizational behaviour or human relations since these areas are covered in other business courses. Therefore an engineering or science student taking only one innovation or entrepreneurship course will not be exposed to the information needed to develop interpersonal skills. It is important, therefore, that courses for engineering and science students be customized to cover the problems of interpersonal relations and communication in science- or engineering-based organizations.

Another area that does not appear to receive sufficient attention is the marketing of high technology products and processes. The marketing of new products or processes presents unique problems, and conventional marketing approaches cannot always be applied to them. Moreover, traditional market survey methods cannot normally be used for products based on new or emerging technologies since they can provide totally false predictions. For example, early market surveys predicted that the total world market for computers would be for less than a dozen.

RECOMMENDATION 7

Courses on technological innovation or technical entrepreneurship should be customized to meet the specific needs of science and engineering students, especially in the areas of interpersonal relations, communication, and high technology marketing.

The MBA Barrier: Many technological innovation and technical entrepreneurship courses in business faculties are offered as part of MBA programs and are not easily accessed by undergraduate students in science or engineering faculties. Twelve of the 17 technological innovation courses and six of the seven entrepreneurship courses offered by Canadian business faculties are at the MBA level. Non-MBA students can only take these courses if there is room in the class, and if they have taken the prerequisite courses. A few professors offer two versions of a course, one at the MBA level and one at the undergraduate level. This allows easier access by undergraduates in other faculties.

Where expertise already exists within business faculties, the business school professors should develop undergraduate technological innovation or technical entrepreneurship courses that take into account the concerns expressed in the preceding section.

RECOMMENDATION 8

Professors should be encouraged to develop undergraduate versions of their MBA-level courses on technological innovation or technical entrepreneurship that meet the specific needs of science and engineering students and do not have any prerequisites.

As noted in chapter 5 there is a need to incorporate information on technological innovation into courses currently offered by Canadian business schools.

RECOMMENDATION 9

Canadian faculties of business should integrate information on technological innovation and technical entrepreneurship into all the courses offered within the business faculty, in addition to providing specific courses on technological innovation and entrepreneurship to business students.

Level of Research Effort in Canada: Canada lags far behind the United States (see appendix 3) and the United Kingdom in research in technological innovation and entrepreneurship, and in establishing centres of expertise in these areas. The United States has, for example, the Center for Policy Alternatives at the Massachusetts Institute of Technology, and the United Kingdom has the Science Policy Research Unit at the University of Sussex and the R&D Research Unit at the University of Manchester. In contrast, Canada does not have one centre of expertise that provides courses at the masters or doctoral level and conducts indepth research into technological innovation or technical entrepreneurship. The pockets of expertise that we do have are, in the main, below critical mass. The "Entrepreneurship and New Venture Development" program at the University of Calgary comes closest to the centre of excellence concept. McMaster University and Queen's University are attempting to develop centres but they are only just starting and their success is not assured. In terms of courses only, the École Polytechnique, the University of Ottawa, and the University of Waterloo have the largest offerings but conduct little research. Federal and provincial governments, as well as industry, should support the existing efforts of universities to develop and strengthen their innovation and entrepreneurship centres.

The National Science Foundation in the United States is considering funding four or five regional centres of expertise in technological innovation. Canada should support at least two or three similar centres to conduct research and provide training at the doctoral level in technological innovation or technical entrepreneurship.

RECOMMENDATION 10

Federal and provincial governments, as well as industry, should support the establishment of two or three world-class centres of expertise in the areas of technological innovation and technical entrepreneurship.

CONCLUSION

There has been a dramatic growth in the number of courses in technological innovation and technical entrepreneurship in the past five years, with most of the courses being located in Ontario and Quebec.

The need for courses or seminars in technological innovation or technical entrepreneurship for engineering and science students is recognized by many deans of engineering and science. However, considerable financial and attitudinal barriers must be overcome in order to spread the present number of courses beyond the eight engineering faculties currently offering innovation or entrepreneurship courses and to establish the first course in a science faculty.

Without financial assistance from either provincial or federal governments, there is little chance that new courses will be developed, and there is a real possibility that some of the existing courses will be shelved.

The attitude of academics, especially those in the faculties of science, toward interaction with society must change before the spread of innovation or entrepreneurship courses will take place. As one dean of science at a major Canadian university said:

> I am certainly, completely convinced that the ivory tower image of the university, to the extent that it still exists, has got to disappear, and a closer relationship between what is taught and what is required would be a very beneficial situation. There is a need to change the attitudes in the university, in the departments, and among individual staff members as to what the role of education is in order to get them convinced that they should be looking at these sorts of educational options.

We need to encourage the academic mavericks who see the need for innovation and entrepreneurship training and provide them with the resources to expand the circle of students they can reach. We need to support the development of customized innovation and entrepreneurship courses in engineering, science, and business faculties that meet the needs of innovators and technical entrepreneurs.

Canada should be able to support at least two centres of expertise in the areas of technological innovation or technical entrepreneurship to provide education and training for future university professors and industry consultants, and to establish a strong Canadian research base in these disciplines. We also need to encourage graduate students to enrol in masters and doctoral level programs by providing scholarships.

Technological innovation and technical entrepreneurship can be Canada's ticket to membership in the small group of industrialized countries in the 21st century. The price of the ticket will be a broader awareness by all Canadians, and in particular engineers, scientists and managers of the key role that technological innovation can play in our economic future.

APPENDIX 1

OUTLINES OF COURSES DEALING WITH THE MANAGEMENT OR PROCESS OF TECHNOLOGICAL INNOVATION*

* Courses are listed in alphabetical order according to university. This appendix is based on material provided by the course instructors or faculty deans and includes industrial marketing courses that deal with new product development. Texts are listed if such information was provided.

University of Alberta

Managing in a Technical Environment

Instructor/contact: Jim Sprague

Faculty: engineering — Course no.: MEC 613

Level: undergraduate — Established: 1986

Comment: will be offered in the first term of 1986; it has no prerequisites.

Topics: the design of fully integrated systems (starting a new business, major reasons for business failure, scope and depth of small business feasibility studies); project management (organizing and managing engineering projects, comparison of matrix and traditional management organization); management by objectives (implementation and problems); management of people (motivation theories, management theories).

Engineering and Society

Instructor/contact: Jerry M. Whiting

Faculty: engineering — Course no.: ENG G 405

Level: undergraduate — Established: 1987

Comment: will be offered in 1987 to third- or fourth-year commerce or engineering students. An interpretive course on the art and science of engineering, it presents a brief review of the evolution of engineering, and an analysis of its present role in business and society.

Topics: differences between science and engineering; the roles that engineering plays in business, the economy, national and provincial policy, law and society; relationships of engineering economics and business economics; managing technology-based organizations; an engineering perspective on problems facing business and society; present status of Canada's business and economy; Canada's business and economic future.

Product Management and Product Development

Instructor/contact: H. Clifton Young

Faculty: business — Course no.: MARK 569

Level: MBA — Established: 1986

Comment: earlier versions of this course were taught in 1974, 1975, and 1976 at MBA and undergraduate levels. A new version is currently being developed.

Topics: environment of product management; future shock: the effects of change on people; Third Wave: the changing society; what is product management?; tools for product service management; the product development process; concepts and generalizations; evaluation; commercialization; public policy and the future.

Texts:

J.M. Choffray and G.L. Lilien, Market Planning for New Industrial Products (New York: John Wiley, 1980).
D.F. Midgley, Innovation and New Product Marketing (London: Croom Helm, 1977).
E.A. Pessemier, Product Management: Strategy and Organization, 2nd edition (New York: John Wiley, 1982).

University of Calgary

Management of Technological Innovation

Instructor/contact: Pier Abetti

Faculty: management
ENG 619.75

Course no.: MOHR 799 MECH

Level: graduate

Established: 1986

Comment: a special offering of one of Dr Abetti's regular courses at Rensselaer Polytechnic Institute (RPI). Course objectives are to provide an understanding of the process, management, risk, and rewards of technological innovation and of technology transfer.

Topics: the role of technological innovation in industry; the RPI incubator program and technology park; the process of technological innovation and technology transfer; technology forecasting (delphi); technology planning; market and sales forecasting; transfer of technology; new product development; organizing for innovation and new product development; analysis of innovations in large companies.

Texts:

M.J.C. Martin, Managing Technological Innovation and Entrepreneurship (Reston, Va.: Reston Publishing, 1984).
Readings on the Management of Innovation, ed. Michael L. Tushman and William L. Moore (Boston, Mass.: Pitman, 1982).

Carleton University

Interactions in Industrial Society

Instructor/contact: Jules Lukasiewicz

Faculty: arts (interdisciplinary studies)

Course no.: TSE 59.300

Level: undergraduate

Established: 1972

Comment: gives an overview of the problems of industrial society; makes extensive use of outside speakers.

Topics: history of technology; growth, population development; effects of technology on the environment; renewable resources; technological hazards; nonrenewable resources; energy summary; transport technology and society; modern communications and society; medical technology and ethics; complexity of industrial society; technology and international affairs.

Texts:

J.G. Burke and M.C. Eakin, Technology and Social Change (Boston, Mass.: Boyd and Fraser, 1979).

Peeter Kruus and Mark Shaver, Interactions in Industrial Society (Ottawa: Carleton University, 1984).

Technology and Society: Assessment

Instructor/contact: Peeter Kruus

Faculty: arts

Course no.: TSE 59.401

Level: undergraduate

Established: 1981

Comment: addresses the problem of assessing technological changes and their impact on society and the environment; makes extensive use of outside speakers.

Topics: history of technology assessment; risk analysis and identification; risk analysis of large systems; assessment of nuclear energy; methods of technology regulation; regulation of pesticides; assessment of transport systems; benefit and cost analysis; technology -- law interactions in communications; renewable resource management in Canada's north; ethics in biology and medicine; retrospective assessment of automation; acid rain; transfer of appropriate technology to other countries.

Text:

Peeter Kruus and Mark Shaver, Interactions in Industrial Society (Ottawa: Carleton University, 1984).

Technology and Society: Forecasting

Instructor/contact: Peeter Kruus

Faculty: arts

Course no.: TSE 59.402

Level: undergraduate

Established: 1981

Comment: covers the methods that can be used for forecasting technological and social change, and some of the factors involved in such change; makes extensive use of outside speakers.

Topics: survey of forecasting methods; surveillance methods and trend extrapolation; technology substitution; successes and failures of forecasting; expert opinion and delphi techniques; normative forecasting; changes in values with culture and time;

relevance trees; project planning; cross-impact matrices; invention and innovation; forecasting in R&D; economic and political forecasting.

Texts:

Through the Eighties: Thinking Globally, Acting Locally, ed. F. Feather (Washington, D.C.: World Future Society, 1980).

Peeter Kruus and David Taylor, Methods and Uses of Forecasting (Ottawa: Carleton University, 1985).

Peeter Kruus and Janice Dawe, Technological Innovation: Process and Effects (Ottawa: Carleton University, 1985).

Technology and Society: Innovation

Instructor/contact: Wim Gilles

Faculty: arts — Course no.: TSE 59.403

Level: undergraduate — Established: 1984

Comment: examines the process of technological and social innovation; its importance, how it occurs, and how it can be managed; makes extensive use of outside speakers.

Topics: innovation in Canada; innovation and economic development; steps in innovation; researching the need for innovation; management of research and development; invention; patents, patenting, and licensing; product design; marketing of technology and know-how; barriers to innovation; social impact of technological innovation; deployment of new technology; entrepreneurship in institutional settings; new ventures creation, planning, and rewards; government support for innovation.

Texts:

Readings in the Management of Innovation, ed. Michael L. Tushman and William L. Moore (Boston, Mass., Pitman, 1982).

Dalhousie University

Managing Technological Innovation and Entrepreneurship

Instructor/contact: M.J.C. Martin

Faculty: management — Course no.: MBA 6553/COM 4534

Level: graduate/undergraduate — Established: 1975

Comment: of particular interest to individuals seeking careers in high technology organizations as scientists, engineers, or managers. The primary thrust of this course is an analysis of the innovation process in high technology businesses.

Topics: the technological innovation and entrepreneurship process; defining the technological base and strategies of the firm; forecasting future technological markets; the R&D setting -- creative thinking; project evaluation and selection;

project management and control; project needs and the personal development of R&D staff; transferring the project from R&D to manufacturing; matrix management; learning curve or technological progress function; the entrepreneurial setting -- incubator organizations; characteristics of entrepreneurs; small business entrepreneurship; stimulating entrepreneurship in large organizations; national technological policies; government programs for supporting technology; Canada's branch-plant economy and truncated technology base; developing a technology base in the Atlantic provinces.

Texts:

M.J.C. Martin, Managing Technological Innovation and Entrepreneurship (Reston, Va.: Reston Publishing, 1984).

M.J.C. Martin and P.J. Rosson, Four Cases on the Management of Technological Innovation and Entrepreneurship, Technological Innovation Studies Program, Report 85 (Ottawa: Department of Regional Industrial Expansion, 1982).

Supplementary texts:

Thomas E. Clarke, R&D Management Bibliography -- 1981 (Vancouver: Stargate Consultants Limited, 1981).

D.S. Scott and R.M. Blair, The Technical Entrepreneur -- Inventions, Innovations and Business (Waterloo, Ont.: Sandford Educational Press, 1979).

David Thomas, Knights of the New Technology: The Inside Story of Canada's Computer Elite (Toronto: Key Porter Books, 1983).

Readings in the Management of Innovation, ed. Michael L. Tushman and William L. Moore (Boston, Mass.: Pitman, 1982).

Thomas J. Peters and Robert H. Waterman, In Search of Excellence (New York: Harper & Row, 1983).

École Polytechnique de Montréal

Elements of Industrial Innovation
(Éléments d'innovation industrielle)

Instructor/contact: Roger A. Blais

Faculty: engineering (University of Montreal) Course no.: SH.400

Level: undergraduate Established: 1980

Comment: available to all third- or fourth-year undergraduate engineering students. Outside quest lecturers are used.

Topics: the Industrial Revolution and the innovation cycle; invention, innovation, and research and development; R&D activity in Canada and elsewhere; the innovation team and the characteristics of an entrepreneur; patents and other forms of intellectual property; invention evaluation factors; value analysis; essential marketing factors; causes of success and failure in new products; planning; technology transfer; starting a technology-based enterprise; government programs supporting innovation; importance of small and medium-sized firms to Quebec.

Text:
Roger Blais, Éléments d'innovation industrielle (Montréal: École Polytechnique de Montréal, 1985).

Technological Forecasting and Development
(Prévision et développement technologique)

Instructor/contact: Roger A. Blais and Michel Normandin

Faculty: engineering (University of Montreal) Course no.: IT.400

Level: undergraduate Established: 1986

Comment: replaces two earlier courses on technological forecasting and invention. The course must be taken in parallel with SH.400.

Topics: technological change; review of principal methods of forecasting; intuitive methods: delphi, expert panels; linear extrapolation; substitution and the FisherPry formula; relevance trees and cross-impact matrices; use of scenarios; dynamic modelling; impact of organization on innovation; planning and study of innovative projects; parametric and value analysis; licensing; creativity methods.

Texts:
Roger Blais, Guide de prévision technologique (Montréal: École Polytechnique de Montréal, 1985).
Y.T. Li, D.G. Jansson, and E.G. Cravalho, Technological Innovation in Education and Industry (New York: Van Nostrand Reinhold, 1980).

New Product Development
(Commercialisation de nouveaux produits)

Instructor/contact: Michael Zins

Faculty: engineering (University of Montreal) Course no.: IT.500

Level: undergraduate Established: 1980

Comment: prerequisites are SH 400 and IT 400.

Topics: the role of marketing in industrial innovation; the importance of new products to the company; market analysis and planning; identifying commercial opportunities; market research; forecasting market potential; launching a new product; study of the product portfolio; organizational buying processes; organizing the development of new products; strategies for developing new products; factors affecting the success and failure of new products; planning the commercial launch of a new product.

Text:
Glen L. Urban and John R. Hauser, Design and Marketing of New Products (Englewood Cliffs, N.J.: Prentice-Hall, 1980).

Technology Transfer

Instructor/contact: J.P. Bonhomme (lawyer)

Faculty: engineering (University of Montreal) Course no.: SH.510

Level: undergraduate Established: 1982

Comment: taught by an outside lecturer.

Topics: definition and scope of technology transfer; major players in technology transfer; study of situations involving transmitters and receivers of technology; selection, training, and role of technology transfer agents; problems of recruiting and training of work teams; measuring the results of technology transfer.

Université Laval

Introduction to the Management of Technology
(Introduction au management de la technologie)

Instructor/contact: Paul-H. Roy

Faculty: engineering Course no.: GCH 17087

Level: graduate/undergraduate Established: 1982

Comment: makes use of outside guest speakers.

Topics: dimensions and dynamics of a technical enterprise; overview of the process of innovation; technological planning; technological substitution; strategic planning; marketing and manufacturing/technology interfaces; project selection and allocation of resources; critical roles in technological innovation; problem-solving techniques; communications in research and development; supervising R&D teams; organizational structure and management styles; commercializing R&D outputs; management of new technology-based firms; modern characteristics of technology management and future perspectives.

McMaster University

Innovation

Instructor/contact: P.M. Banting

Faculty: business Course no.: P 724

Level: MBA Established: 1977

Comment: originally presented as a seminar series; approved as a regular MBA course in 1986.

Topics: Canadian environmental influences on innovation; organizational influences; entrepreneurship and intrapreneurship; technological forecasting; research and development; patents and intellectual property; marketing innovation; industrial design; product and service market-entry strategies; diffusion of innovation; information requirements for innovation.

Text:

M.J.C. Martin, Managing Technological Innovation and Entrepreneurship (Reston, Va.: Reston Publishing, 1984).

Reference books:

Science Council of Canada, Report 15, Innovation in a Cold Climate: The Dilemma of Canadian Manufacturing (Ottawa: Information Canada, 1971).
John N. Britton and James M. Gilmour, The Weakest Link: A Technological Perspective on Canadian Industrial Underdevelopment, Science Council of Canada, Background Study 43 (Ottawa: Supply and Services Canada, 1978).
Thomas J. Peters and Robert H. Waterman, In Search of Excellence: Lessons from America's Best-Run Companies (New York: Harper & Row, 1982).

Product Marketing

Instructor/contact: R.G. Cooper

Faculty: business — Course no.: M735/4MC3

Level: MBA/undergraduate — Established: 1985

Topics: new products: problems and remedies; the new product process; generating new product ideas; evaluating new product proposals; marketing information for new products; research, test marketing, and economic analysis; target market selection; designing the launch strategy; new product strategy; organizing for new products.

University of Manitoba

Issues in Technological Change

Instructor/contact: Marvin Bartell

Faculty: administrative studies — Course no.: 29:308

Level: undergraduate — Established: 1980

Comment: focuses on the process of technological innovation and factors that determine its success; guest lecturers are used.

Topics: focus on Canada in an international perspective; creativity, innovation, entrepreneurship; applications of technological innovation; the organization: climate, leadership, teams, conflict, communication and productivity; fostering innovation within the firm; patent law and policy; impact of government tariff and science policies; professional careers and stress reactions; economic and financial aspects of industrial innovation; diffusion of innovations.

Texts:

Technological Innovation for a Dynamic Economy, ed. Christopher T. Hill and James M. Utterback (New York: Pergamon Press, 1979).
Edwin Mansfield, The Production and Application of New Industrial Technology (New York: Norton, 1977).
James D. Watson, The Double Helix: A Personal Account of the Discovery of the Structure of DNA (New York: Atheneum, 1968).

Management of Research and Development

Instructor/contact: Marvin Bartell

Faculty: administrative studies — Course No: 29:309

Level: undergraduate/executive — Established: 1983

Comment: presented during an evening summer session in 1983; the course focused on the organization and management of industrial research and development, and on specific inventions and their impact on industry.

Topics: electronics; biomedical technology; entrepreneurship; management of professionals; program management; technological change; telecommunications; technically oriented multinational organizations.

Memorial University

Management of Technological Innovation

Instructor/contact: Michael Skipton

Faculty: business administration — Course no.: B 9003

Level: MBA — Established: 1985

Comment: designed to explore the technological innovation process in the context of its economic importance, and especially its importance to the business firm. The course was originally developed by Dr Skipton in 1982 at the Kingston Polytechnic in the United Kingdom.

Topics: technology transfer, industrial innovation, and economic competitiveness; technological innovation over time; corporate strategic and operational management and technological innovation; environmental change, corporate strategy, technological innovation, and strategic competitiveness; forecasting markets and technologies; technologies and customer needs, offerings, and markets; the organizational setting for change: power, politics, climate, and culture; the organizational setting for change: organization evolution and development; marketing function: relationships to technological innovation; operational management of innovation: R&D management, the management of design, project management, and the management of new product or process development and implementation; the R&D function: creative thinking and organizing for the creative process; the R&D function: staff, staffing, and communications; new

product development; the R&D function: project evaluation and selection; the R&D function: project management and control; the production function: products, processes, projects, and relationships to R&D; the production function: transferring the product or project from R&D to production; entrepreneurship and venturing: small firms and new ventures; government and society: promoting innovation and controlling technology.

Texts:

M.J.C. Martin, Managing Technological Innovation and Entrepreneurship (Reston, Va.: Reston Publishing, 1984).

Readings in the Management of Innovation, ed. Michael L. Tushman and William L. Moore (Boston, Mass.: Pitman, 1982).

University of Ottawa

Innovation Policy and Management

Instructor/contact: Alain Albagli (outside lecturer)

Faculty: administration — Course no.: ADM 6367

Level: MBA — Established: 1983

Comment: aims to provide a better understanding of present innovation policies and their impact on innovation in the private sector. The course underwent a major revision in 1985.

Topics: the case for innovation; R&D in universities, provincial research organizations, and governments; the innovation process; technology transfer and diffusion; intellectual property; the role of government; managerial techniques; organizing for successful innovation; financing; managing projects; evaluating projects.

Managing Technological Risk

Instructor/contact: John C. Nash

Faculty: administration — Course no.: ADM 6381

Level: MBA — Established: 1984

Comment: examines some of the methods by which managers can gain a better insight into managing the risk that technology can pose.

Topics: introduction to risk; estimating the probabilities of events; fault or event-tree analysis; estimating the consequences; expected value criteria; minimax and regret criteria; perception of risk; consequences of public policy; cost-benefit approaches to risk management; case studies in medicine, radiation hazards, pharmaceuticals.

Text:

E.A. Crouch and Richard Wilson, Risk-Benefit Analysis (Cambridge, Mass.: Ballinger Publishing, 1982).

Creativity and Innovation

Instructor/contact: Jérome A. Doutriaux

Faculty: engineering

Course no.: EMP 5111

Level: Graduate

Established: 1982

Comment: forms part of the university's diploma in engineering management program; oriented toward engineers and applied scientists.

Topics: the case for innovation; Canadian environment for product or process development and innovation; technology transfer to the private sector from government and university laboratories; the product development process; R&D project selection and management procedures; managing technical professionals; financing technical innovation; incentive programs and patents; technical entrepreneurship; starting new ventures policies: Canada and other industrial countries.

Industrial and Technology Marketing

Instructor/contact: R.M. Cuthbert

Faculty: administration

Course no.: ADM 6326

Level: MBA

Established: 1986

Comment: central objective is to enhance students' ability to make strategic decisions in firms that sell industrial products and services. Particular attention is given to the marketing of high technology products.

Topics: industrial marketing system; industrial customer; organizational buying; organizational demand analysis; planning industrial marketing strategy; industrial channel strategy; industrial product strategy; industrial product life cycle; selling in the industrial market; managing industrial pricing; after-sales service; marketing complex technology and industrial systems.

Texts:

R.W. Haas, Industrial Marketing Management, 2nd edition (Boston, Mass.: Kent Publishing Co., 1982).

R.M. Cuthbert, Management of Industrial Marketing Channels, 3rd ed., (Ottawa: Macrae Publishing, 1986).

Technology Policy and R&D Management

Contact: D.S. Necsulescu

Faculty: engineering

Course no.: EMP 5112

Level: graduate

Established: 1982

Comment: forms part of the engineering management diploma program; the course has never been presented.

Topics: relationship between R&D and economic progress; elements of Canadian policy on technology; R&D activities in the private and public sectors; government incentives and support programs; comparison with the policies of other industrial countries; technology planning; technology forecasting; R&D management: staffing, structure.

Université du Québec à Montréal

Technology and Innovation

Instructor/contact: Roger E. Miller

Faculty: business | Course no.: MBA 8014

Level: MBA | Established: 1980

Topics: technology and economic development; the technological dimension of the evolution of industries; dynamic competitiveness of emerging industries; innovation cycle and technological strategies; corporate entrepreneurship; new product development; management of research and development; internal ventures; launching an enterprise; venture capital; public policies and technological innovation.

Text:
Roger Miller et coll., La direction des entreprises : concepts et applications (Montréal: McGraw-Hill, 1985).

Queen's University

Management and Technology

Instructor/contact: Peter Richardson

Faculty: business | Course no.: BUS 976

Level: MBA | Established: 1976

Topics: the role of technology in society; innovation in society; innovation and the firm; successful innovation; project selection and termination; project control; project start-up; management of the project; technology-based strategies; corporate venturing; the role of research and development; implementation of project management; organizing for innovation.

Technical University of Nova Scotia

Managing Technological Innovation

Instructor/contact: M.J.C. Martin (outside lecturer)

Faculty: engineering

Course no.: NT 0042

Level: undergraduate

Established: 1986

Comment: examines the process by which a scientific or engineering invention is developed into a socially useful and commercially successful innovation in technology-based companies. The course introduces students to the major functional areas of business and the important behaviourial issues involved, and identifies some of the paths open to individuals who wish to pursue management careers in which they can use their engineering backgrounds.

The course also examines the factors involved in launching new technology ventures and in maintaining a healthy spirit of technological entrepreneurship within them as they grow into larger companies. Current examples of high technology companies are used to illustrate the problems and issues addressed throughout the course.

Texts:

M.J.C. Martin, Managing Technological Innovation and Entrepreneurship (Reston, Va.: Reston Publishing, 1984).
M.J.C. Martin and P.J. Rosson, Four Cases on the Management of Technological Innovation and Entrepreneurship, Technological Innovation Studies Program, Report 85 (Ottawa: Department of Regional Industrial Expansion, 1982).

University of Waterloo

Technological Innovation and its Management

Instructor/contact: Michael Volker (outside lecturer)

Faculty: engineering

Course no.: SY DE 466

Level: undergraduate

Established: 1974

Comment: deals with factors that influence technological innovation.

Topics: the hi-tech industry in Canada vis-à-vis that in the United States, Japan, and other countries; innovation versus invention; factors leading to successful innovation; innovative companies; economics of innovation; financial markets -- role in R&D; introduction to marketing; the four Ps of marketing; product life cycle; how and where to obtain information; innovation traps; team-approach to problem solving; competitive strategy and organizational design.

Texts (recommended, not required):

M.J.C. Martin, Managing Technological Innovation and Entrepreneurship (Reston, Va.: Reston Publishing, 1984).

Christopher Freeman, The Economics of Industrial Innovation, 2nd edition (Cambridge, Mass.: MIT Press, 1982).
Readings in the Management of Innovation, ed. Michael L. Tushman and William L. Moore (Boston, Mass.; Pitman, 1982).

Patenting for Engineers

Instructor/contact: Alan M. Hale

Faculty: engineering | Course no.: ME 402

Level: undergraduate | Established: 1986

Comment: designed to provide an awareness of the intellectual property rights that will be or can be associated with professional activities such as design, product, or software development.

Topics: intellectual property; history and legal context; value of intellectual property, ownership issues; copyright, trade marks, industrial design, trade secrets; trade secrets versus patents; improving the quality of patents through the application of formal design methodology; record keeping, the inventor's workbook; patents as a source of valuable public-domain technology; patent searching: in selected libraries, using computerized databases, at patent offices, by professionals; patentability: what can be patented, patentable subject matter, novelty, non-obviousness, and utility; parts of a patent application and their importance, preparing a patent application; patent claims: interpretation and drafting; examination of the patent application, dealing with the examiner; foreign patenting, exploitation of intellectual property; intellectual property litigation; technology licensing.

Text:
Alan M. Hale, Patenting Manual, 2nd edition (Buffalo, N.Y.: S-P I, 1983).

University of Western Ontario

Management of Technology

Instructor/contact: Albert R. Wood

Faculty: business administration | Course no.: 674/474

Level: MBA/undergraduate | Established: 1970

Comment: taught by the case method. The course follows the management of technology through its life cycle. It starts with the management of the innovation process and decisions about starting, ending, and modifying innovative undertakings. It then examines separately the two main areas of technological change -- new product and new process development. New process technology is examined in terms of its impact on the firm and key management concerns such as timing and implementation.

Next, the course examines project management for new products; it looks at project organization, planning and control, and the role of the project manager. Finally it examines the management of technology from the point of view of top management. Technological strategies on both a company and a national basis are examined. Throughout the course, technology is looked at from the manager's, rather than the technologist's, viewpoint.

Texts (recommended reading only):
M.J.C. Martin, Managing Technological Innovation and Entrepreneurship (Reston, Va.: Reston Publishing, 1984).
Brian Twiss, Managing Technological Innovation, 3rd edition (White Plains, N.Y.: Longman, 1986).
Readings in the Management of Innovation, ed. Michael L. Tushman and William L. Moore (Boston, Mass.: Pitman, 1982).

Wilfred Laurier University

Management of New Technology

Instructor/contact: Hamid Noori

Faculty: business and economics — Course no.: BUS 655

Level: MBA — Established: 1984

Comment: examines some of the technical, social, and economic issues concerning the acquisition and implementation of new technology. A number of related topics including productivity and quality improvement, flexibility, product/process interface, and strategic importance of new technology are discussed.

York University

Management of Creativity and Technological Innovation

Instructor/contact: Thomas E. Clarke (outside lecturer)

Faculty: administrative studies — Course no.: BEHS 621

Level: MBA — Established: 1979

Comment: examines the many complex factors that stimulate and inhibit individual and group creativity in organizations. Emphasis is placed on the management of research and development. The course was not presented after 1980 due to lack of a local lecturer.

Topics: the technological innovation process; the firm's technological strategy; determinants of successful and unsuccessful technological innovation; R&D project/venture evaluation; organizing for technological innovation; role and style of the R&D manager; creativity and the brain; motivation of R&D personnel --

reward systems; organizational climate, age and creativity; communication flow in an R&D laboratory; technology transfer; Canadian technology policy and programs.

Text:

Donald Pelz and Frank Andrews, Scientists in Organizations: Productive Climates for Research and Development (Ann Arbor Institute for Social Research, University of Michigan, 1976).

Strategic Management of Technology-Based Firms

Instructor/contact: Jerry Dermer

Faculty: administrative studies

Course no.: PLCY 6950

Level: MBA

Established: 1984

Comment: focuses on the linkages between technology and management strategy, and how strategy is different when technology is the key strategic variable.

Topics: strategy-technology linkages; competing in technology-driven industries; technological evolution; industry evolution; managing innovative new ventures; managing the technologically innovative firm; managing scientists and R&D; planning, resource allocation, and control systems; role of government/international perspective.

APPENDIX 2

COURSES ON TECHNICAL ENTREPRENEURSHIP*

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*Courses are listed in alphabetical order by university.

This appendix is based on material provided by the course instructors or faculty deans.

University of Alberta

Organizational Analysis

Instructor/contact: Charles Lee

Faculty: business

Course no.: OA 552/445

Level: MBA/undergraduate

Established: 1982

Comment: presented under a special projects designation, the course uses the problems of actual inventors as the teaching vehicle. The university advertises for inventors who can provide live cases and supply an inventor with a business plan.

Topics: marketing and sources of market information; patents and intellectual property; sources of government assistance; spreadsheets and financial planning; sources of venture capital; sources of technological assistance; Canadian standards.

Text:

Jeffry A. Timmons, Leonard E. Smollen, and Alexander L.M. Dingee, jr., New Venture Creation: A Guide to Small Business Development, 2nd edition (Homewood, Ill.: Irwin, 1985).

University of Calgary

New Venture Entrepreneurship

Instructor/contact: W. Ed McMullan

Faculty: management

Course no.: MOHR 481

Level: undergraduate

Established: 1976

Comment: aims to provide an overview of the process of initiating a new venture and developing it into a self-sustaining enterprise.

Topics: introduction to entrepreneurship; entrepreneurial experiences; classics in entrepreneurial thought; understanding entrepreneurship; opportunity identification exercise; preparing the framework; learning to perform; capitalizing on demonstrated performance.

New Venture Entrepreneurship

Instructor/contact: W. Ed McMullan

Faculty: management

Course no.: MOHR 781

Level: MBA

Established: 1976

Comment: aims to provide an overview of the process of initiating a new venture and developing it into a self-sustaining enterprise. The course will emphasize opportunity identification.

Topics: introduction to entrepreneurship; understanding entrepreneurship; practising strategic venture development.

Texts:

W.E. McMullan, W. Long, and K.H. Vesper, New Venture Development: The Entrepreneurial Option, manuscript, to be published by Harcourt, Brace and Jovanovich in 1988.

W.E. McMullan, The First Five Years of a High Technology Enterprise, manuscript.

H.H. Stevenson, M.J. Roberts, and H.I. Grousbeck, New Business Ventures and the Entrepreneur (Homewood, Ill.: Irwin, 1985).

New Venture Marketing

Instructor/contact: W.A. Long and N. Ohtani

Faculty: management — Course no.: MRK 785

Level: MBA — Established: 1974

Comment: primarily addresses the growth and development of new ventures based on a new product; emphasizes new product feasibility. Students are required to complete a feasibility study of a potential new product or service submitted for consideration by local businesses. The course underwent a major revision in 1984.

Text:

C. Merle Crawford, New Products Management, (Homewood, Ill.: Irwin, 1983).

École Polytechnique de Montréal

Entrepreneurship and the Study of Emerging Enterprises
(Entrepreneurship et gestion d'une entreprise émergente)

Instructor/contact: Jacques C. Martin (outside lecturer)

Faculty: engineering (University of Montreal) — Course no.: IT.510
Level: undergraduate — Established: 1980

Comment: courses SH.400 and IT.400 are prerequisite for this course, which should be taken in conjunction with IT.500.

Topics: the entrepreneurial phenomena in Canada, Quebec, and the United States; the role of incubators in the education of entrepreneurs; new business start-up: problems, stages, barriers to avoid; choosing your partners; alternatives in starting a business: franchising, licensing, buying an existing business; sources of new ideas and innovative products; production planning, including subcontractors, and location of equipment; budgeting and finance; sources of short- and long-term financing;

locating and obtaining risk capital; equity financing; importance of human resources; leadership and motivation of employees; measures of productivity; importance of strategic planning.

Texts:

Roger Miller et coll., La direction des entreprises : concepts et applications (Montréal: McGraw-Hill, 1985).
Jean-Marie Toulouse, L'Entrepreneurship au Québec (Montréal: Fides, 1980).

Université Laval

Process of Entrepreneurship
(Processus d'entrepreneurship)

Instructor/contact: Yvon Gasse

Faculty: sciences de l'administration — Course no,: MNG - 63449

Level: MBA — Established: 1985

Comment: part of an MBA option on the management of small and medium-sized firms.

Topics: nature of entrepreneurship; the new entrepreneurs; importance of entrepreneurship; characteristics of entrepreneurs; motivation of entrepreneurs; socio-demographic profile of entrepreneurs; environment as an incubator; factors and conditions that encourage entrepreneurship; impact of technological advances on entrepreneurship; cultural factors affecting entrepreneurship; types of entrepreneurs -- technical entrepreneurs.

Texts:

Peter Drucker, Les entrepreneurs (Paris: Les Éditions d'organization, 1985).
George Gilder, L'esprit d'entreprise (Paris: Fayard, 1985).
G.P. Sweeney, Les nouveaux entrepreneurs (Paris: Les Éditions d'organisation, 1982).
Donald S. Scott and Ronald M. Blair, The Technical Entrepreneur (Waterloo, Ont.: Sandford Educational Press, 1979).
Michel Cahier, Les impatients ou la folie de creer (Paris: Les Éditions Robert Laffont, 1980).
C.A. Kent, D.L. Sexton, and K.H. Vesper, Encyclopedia of Entrepreneurship (Englewood Cliffs, N.J.: Prentice-Hall, 1982).
Jean-Marie Toulouse, L'entrepreneurship au Québec (Montréal: Fides, 1980).

Université du Québec à Trois-Rivières

Creativity, Innovation, and Entrepreneurship
(Créativité, innovation et entrepreneurship)

Instructor/contact: Pierre-André Julien

Faculty: administration — Course no.: ADM 6001

Level: graduate Established: 198?

Comment: the factors that stimulate creativity in an organization and the processes by which creativity results in innovation. The emphasis is on small firms.

Topics: definition of creativity; barriers to creative thinking; how to recognize and overcome the barriers; tools and techniques that encourage creative thinking; definition of innovation; mechanisms of innovation: finance and production; organizational strategies that encourage innovation; characteristics of the entrepreneur: motivations; the entrepreneur's role in private and public organizations; the entrepreneur and innovation; the entrepreneur and risk.

Queen's University

Market-Oriented Design

Instructor/contact: Robert D. de Pencier

Faculty: engineering (mechanical) Course no.: MECH 492/493

Level: undergraduate Established: 1969

Comment: a project-oriented course that aims to encourage and enhance, in interested students, qualities related to invention, innovation, and entrepreneurship. The course involves the development of a real product. It underwent a major revision in 1983-84.

Topics: product search; starting and operating a product based new business; selection of a product; preparing a business plan (marketing/retailing); understanding and improving design; getting information; general design approaches; developing a marketing plan; creativity and invention; production, costing, pricing; patents, trade marks, and licensing; sources of new venture funding; industrial design and graphics; entrepreneurship in action; preparing advertisements and brochures; forms of business association; the business of invention; general management of small business; developing products in an industrial environment; accounting, bookkeeping, and tax; histories of successful products; business plan assessment.

Université de Sherbrooke

The Entrepreneur and the Creation of an Enterprise
(L'entrepreneur et la création d'une entreprise)

Instructor/contact: Jean Robidoux

Faculty: administration Course no.: ADM-752

Level: MBA Established: 1971

Topics: principal characteristics of the entrepreneur; should you become an entrepreneur?; profiles of successful entrepreneurs; fundamental distinctions

between an entrepreneur and a manager in terms of aptitudes and attitudes; launching an enterprise; risk and the perception of business opportunities; principal sources of innovative ideas; creativity and innovation; the special experiences of the "new wave" entrepreneurs; government programs to stimulate entrepreneurship; financing new enterprises; marketing and the new product or service; commercial strategies and product differentiation; franchising and acquiring an existing business; entrepreneurship in large organizations.

Text:

Robert Ronstadt, Entrepreneurship: Bibliography 1985 (Dover, Mass.: Lord Publishing, 1984).

University of Toronto

Innovation and Entrepreneurship

Instructor/contact: J.C. Paradi and A.J. Szonyi

Faculty: applied science and engineering — Course no.: CHE 457S

Level: undergraduate — Established: 1974

Comment: introduces the student to business concepts and the methods required to start a small business in Canada.

Topics: profile of the entrepreneur; venture search; innovation, invention; small business environment; legal forms of organization; partnership/interface MBA/PEng; business plan; market research; sources of finance; what makes a business tick; sales and marketing; management and leadership styles; financial and accounting controls; EDP/risk management; survival financing, government assistance programs; business and the law -- patents, licences, trademarks; exporting and importing.

Text:

Andrew J. Szonyi and Dan Steinhoff, Small Business Management Fundamentals, 2nd edition (New York: McGraw-Hill, 1983).

The Business of Software

Instructor/contact: Ron Baecker

Faculty: management studies — Course no.: BUS 2715

Level: graduate — Established: 1986

Comment: presents a broad overview of the software industry and a detailed look at the principles for operating successful new and growing businesses; makes extensive use of guest speakers.

Topics: computer and software industries; software business definition and planning; software market and product planning; management of innovation, R&D, and

software development; software product marketing; software sales and sales management; marketing communications and technical writing; software product manufacturing and support; financing and financial management of high technology ventures; human resource management; development of high technology industries.

University of Waterloo

Entrepreneurship for Engineers

Instructor/contact: D.S. Scott, P.L. Silveston

Faculty: engineering (chemical engineering) Course no.: CE 501

Level: undergraduate Established: 1975

Topics: the climate for innovation and for small business; personal characteristics of entrepreneurs and innovators; review of the innovation process; aids and incubators for innovation; barriers to innovation in the economy; business organization; business plans; raising capital; financial crises; marketing products from a small business; organization and management.

Text:
Donald S. Scott and Ronald M. Blair, The Technical Entrepreneur (Waterloo, Ont.: Sandford Educational Press, 1979).

Technical Entrepreneurship

Instructor/contact: Robert H. Grasley (outside lecturer)

Faculty: engineering Course no.: GE 352

Level: undergraduate Established: 1984

Comment: originally developed and presented at York University's faculty of management in 1979. The objective of the course is to introduce technically trained students to the concept of entrepreneurship and how it is successfully practised.

Topics: the Canadian business scene; psychological aspects of entrepreneurship; structures in business: their format and application; evaluating new ventures; identifying your market; planning for the future; electronic spreadsheets and their uses; capital structures in new ventures; developing your business plan; buying a business or a franchise; failure: the downside of venturing; identifying useful resources.

Text:
Jeffry Timmons et al., New Venture Creation: A Guide to Small Business Development, 2nd edition (Homewood, Ill.: Irwin, 1985).

University of Western Ontario

New Enterprise Management

Instructor/contact: Russell M. Knight

Faculty: business administration Course no.: 642/442

Level: MBA/undergraduate Established: 1972

Comment: designed to teach the student how to start or invest in a new company. Firms examined are innovative in terms of product, service, or concept. This course is taught by the case method.

Topics: exploring for new enterprise opportunities; developing a management team for the new enterprise; evaluating the potential success of a venture; sources of financing for new enterprises; structuring and negotiating financing and purchasing; designing a business plan for a new enterprise; marketing: consumer analysis, pricing, distribution, and promotion; production: product design, process design, and facilities planning; personnel: planning the management and organizational structure of the new enterprise; distinctive strategy: what makes the new enterprise different and likely to be highly successful.

Texts:

Russell M. Knight, Small Business Management in Canada, McGraw-Hill Ryerson Series on Canadian Marketing and Management (New York: McGraw-Hill Ryerson, 1981).

Peter McQuillan and Howard Taylor, Sources of Venture Capital in Canada: A Canadian Guide (Ottawa: Department of Industry, Trade and Commerce, 1978).

Canada, Federal Business Development Bank, ABC 1984: Assistance to Business in Canada: A Handbook of Federal Assistance Programs, 3rd edition (Montreal, 1984).

Ontario, Ministry of Industry and Trade, Starting a Small Business in Ontario (Toronto, 1985).

APPENDIX 3

AMERICAN INNOVATION AND ENTREPRENEURSHIP COURSES*

* This appendix is based on a study of the literature relating to the graduate and undergraduate programs and courses on technological innovation or technical entrepreneurship in American universities. It is not intended to be a comprehensive review but to suggest the level of effort in these areas. Course outlines for a sample of American courses are provided.

Technological Innovation

Graduate-level study programs in the management of innovation and R&D are offered by several universities in the United States. The Sloan School of Management at the Massachusetts Institute of Technology, (MIT) and the Technological Institute of Northwestern University were the first to offer such programs. The programs at both institutions were started in the 1960s by Albert Rubenstein, who is currently at Northwestern University. Northwestern has now awarded over 30 PhD degrees in the management of innovation.

Courses or programs in the management of technological innovation are also offered at Columbia University, the University of Michigan, Purdue University, Yale University, Lehigh University, Pennsylvania State University, the University of Pennsylvania, Rennselaer Polytechnic Institute (RPI), Syracuse University, and Stanford (the last four of these offer degree options). At Carnegie-Mellon, Lehigh, Northwestern, the University of Pennsylvania, RPI, Stanford, and Yale, the engineering schools are involved in the delivery of the innovation courses.[67] In addition to providing courses, these universities also conduct management research in the management of technological innovation.

Among the study programs at MIT is a mid-career, full-time, 12-month program in the management of technology, which is offered jointly by the Sloan School of Management and the school of engineering. The program, which requires thesis research, leads to an MSc and is second to finance in popularity. Subjects taught include: managing technical professionals; the R&D process: communication and problem solving; marketing and technology interface; technology strategy; the manufacturing and technology interface; corporate strategies for managing research, development, and engineering; international technology; new technical ventures; engineering systems analysis; managing technology and innovation; health technology; quality management; manufacturing strategy.

Stanford University offers a technology management program at the master's and doctoral levels. It is offered jointly by the schools of business and engineering. The core courses include: managing technology for competitive advantage; industrial management; new enterprise management; automation and work; R&D management; doctoral seminar in technology management; manufacturing strategy; managing corporate technology and innovation; strategic management of manufacturing; management of computers and information systems.

The faculties at both Stanford and MIT conduct research in the management of technological innovation.

Under the direction of David L. Wilemon, the school of management at Syracuse University offers an MBA in innovation management. Topics in this program include: entrepreneurship and new enterprise development; strategic planning for innovative industries; environmental influences on innovation; the innovative firm and its markets; managing innovative products and new ventures; marketing strategies for the diffusion of innovations.

One of the most widely known short courses in the management of technological innovation is the MIT summer session course, "The Management of Research, Development, and Technology-Based Innovation." This two-week course, directed by Ed Roberts, covers topics such as: the process of technological innovation; managing the technical problem-solving process; staff selection, development, and motivation; induction of the new employee to increase performance; effect of laboratory design and

organizational structure on technical communications; the role of the technological gatekeeper; supervising RD&E teams and technical groups; avoiding the "not invented here" syndrome; forecasting technological change and its impact; selecting and planning RD&E projects; project, functional, and matrix management approaches; managing large-scale programs; relating RD&E to marketing and production; organizing and managing technical venture programs; designing an overall technical strategy; business-government interface on technology transfer.

In addition to courses on technological innovation, over 100 schools teach engineering management. Some of the courses within these engineering management programs focus on technological innovation. The University of Missouri -- Rolla engineering program contains courses in the management of innovation and entrepreneurship, entitled "Human Behaviour for Engineering Management," "Management for Engineers," "Technical Entrepreneurship," and "Project and Systems Management."

Technical Entrepreneurship

In a 1985 survey of 570 schools of business and 267 schools of engineering, Karl Vesper found that 212 schools of business (eight Canadian) and 41 schools of engineering (three Canadian) located in 245 institutions of higher education give entrepreneurship courses. Eight institutions had entrepreneurship courses in both their business and engineering schools.[68] Most of the entrepreneurship courses in Vesper's survey are general, and not dedicated to the start-up of technology-based businesses. The number of institutions offering entrepreneurship courses in the United States and Canada has increased from nine in 1967; 133 in 1976, and 163 in 1980.

Vesper found that the following American engineering schools provided entrepreneurship courses: Brigham Young University, Bucknell University, California State University at Northbridge, Catholic University of America, Clarkson University, Colorado State University, Dartmouth College, Drexel University, George Washington University, Georgia Institute of Technology, Illinois Institute of Technology, Iowa State University, Johns Hopkins University, Massachusetts Institute of Technology, University of Massachusetts, Michigan Technological University, Milwaukee School of Engineering, University of Missouri - Rolla, University of Nebraska at Lincoln, University of Nevada - Reno, New Jersey Institute of Technology, University of New Mexico, New Mexico Institute of Mining and Technology, New Mexico State University, Northwestern University, Nova/New York Institute of Technology, University of Pennsylvania, Rochester Institute of Technology, Rose-Hulman Institute of Technology, S.U.N.Y.-Maritime, Stanford University, University of Tennessee at Chatanooga, University of Tennessee at Knoxville, Texas A&M University, University of Utah, Western New England.

In addition, the following American universities offer, through their business schools, entrepreneurship courses that appear to be oriented, in some degree, toward technical entrepreneurship: University of California - Los Angeles, Carnegie-Mellon University, Dartmouth College, George Washington University, New Mexico Highlands University, University of Oregon, University of Pennsylvania, Rensselaer Polytechnic Institute, Stanford University.

The Vesper survey also identified innovation management courses at Case Western Reserve and Drexel University.

According to Vesper, the Harvard Business School and the Wharton Business School (University of Pennsylvania) have massive and especially well-financed programs in

entrepreneurship. The Wharton Entrepreneurial Centre, founded in 1973 by Edward Shils, offers a three-part program that includes: clinical programs, seminars, conferences, and dinner presentations; academic research and publications; courses at both the undergraduate and graduate levels.

Among the six courses offered in the entrepreneurial area is one entitled "Technological Venture Development." This course deals with the following topics: the invention process; formulation of business plans; financing opportunities including private offerings, limited partnerships, and venture capital placements; and protection of intellectual property.

The Centre for Entrepreneurial Studies at Babson College was set up in 1978. It is now a major centre for entrepreneurial research in the United States. In addition, Babson offers programs at both the undergraduate and MBA levels. Graduate level courses include "Entrepreneurship" and "Financing the Entrepreneurial Venture."

In the mid-1970s, the National Science Foundation established four industrial innovation centres to promote the development of technical entrepreneurship in the United States. A recent review of the American innovation centres concluded that the innovation and entrepreneurship courses offered by the centres assisted in, "fostering a new generation of inventors and entrepreneurs."[69]

Although there has been a dramatic increase in the number of general courses on entrepreneurship in the United States since 1976, the number of courses dealing with technical entrepreneurship is still quite small.

The following are technological innovation or technical entrepreneurship course outlines from several American universities. They are presented in alphabetical order according to university.

Drexel University

Managing the Front End of Innovation

Instructor: Alan Glasser

Topics: an overview of the management functions with regard to innovation; an exploration of the management attributes at all levels of the firm showing the subtle and overt interactions with innovation and the effects thereon; an explicit rendering of all the direct factors that affect innovation, for example: providing direction, making resources available, evaluation procedures, selection of candidate products; problems in innovation illustrating the innovative methods as applied to a series of extremely difficult situations.

Sloan School of Management, Massachusetts Institute of Technology

Corporate Strategies for Managing RD&E

Instructor: E.B. Roberts and Alan M. Kantrow

Faculty: business Course no.: 15.369

Comment: deals with strategic alliances between large and small firms; uses guest speakers.

Topics: strategic alliances in the context of corporate venture strategy; legal issues in alternative approaches to strategic alliances; choosing a venture strategy; experiencing strategic alliances; industrial policy implications of international alliances; strategic alliances in the context of corporate strategy; the changing nature of corporate technology strategy and structure.

New Technical Ventures

Instructor: Eric von Hippel

Course no.: 15.375

Topics: elements of successful ventures; characteristics of successful entrepreneurs; choosing a product and market; presentation of possible venture projects; generation of the product and market analysis portion of a business plan; rapid, economical data collection and analysis techniques; sources of new products, protecting market advantage; effective patent, trademark, and copyright protection; elements of venture capital; internal corporate ventures; the downside: how to go bankrupt (gracefully); the upside: a Sloan Alumnus who made it tells all.

The R&D Process: Technical Problem Solving and Communication

Course no.: 15.371

Topics: the sociology of science; the invisible college; scientific fraud; the sociology of science; contrasting science and technology; relations between science and technology; problem solving and cognition; the role of literature in technology; inter-organizational communication in technology; the technological gatekeeper; organizational structure and communications; university/industry relations; architecture and technical communications; electronic communication and information processing; international communication of technology; the role of the research institute in international technology transfer.

New Mexico Highlands University

Technological Entrepreneurship

Instructor: Wallace Levere

Comment: designed to help students understand the problems and issues facing a new firm (or product in an existing firm) using an invention or technological advance to understand and experience the excitement of being an entrepreneur, and to develop knowledge and elementary skills needed to appraise and develop a significant new technology-based firm.

Topics: evaluation of an innovation; invention, patents, trade secrets, and proprietary knowledge; entrepreneurs: care and feeding; business planning for the new venture; strategies for a new business; formation of a new company; market analysis and planning; product design, planning, and liability; legal issues of a new business; securing seed and venture capital; development of the management team; financial planning and pro formas.

New Mexico Institute of Mining and Technology

Technological Entrepreneurship

Instructor: Gordon R. Bopp

Comment: designed to help students understand the problems and issues facing a new firm (or product in an existing firm) using an invention or technological advance to understand and experience the excitement of being an entrepreneur, and to develop the knowledge and elementary skills needed to develop a significant new technology-based firm.

Topics: innovation evaluation; invention, patents, etc.; entrepreneurs; new venture business planning; new business strategies; formation of a new company; market analysis and planning; product design and planning; legal issues of new ventures; securing seed and venture capital; development of the management team; financial planning and pro formas.

Texts:

G.C. Udell, How To Assess Before You Invest (Seattle, Wash.: Locus, 1982).
Robert C. Ronstadt, Entrepreneurship (Dover, Mass.: Lord Publishing, 1985).

The Technological Institute, Northwestern University

Technical Entrepreneurship Inside and Outside the Company

Instructor: Albert H. Rubenstein and D.N. Frey

Faculty: engineering Course no.: IE/MS D90

Topics: the need for special treatment of some R&D or venture/entrepreneurial (V/E) projects; origins of innovation in the firm; role or context of R&D in the firm; organizational forms for V/E projects; venture or new products division; captive venture capital approach; evaluating and financing internal projects; sources of capital for V/E projects; selecting personnel for V/E projects; incentives and rewards for entrepreneurship; feeding the V/E project into the operating division; commercializing government technology; hi-tech spin-off from the firm; external venture capital approach; sources of venture capital; legal and accounting aspects of V/E projects.

Seminar on Organization of Research, Development, and Engineering

Instructor: Albert H. Rubenstein

Faculty: engineering Course no.: E-11

Topics: the economic role of R&D; relations of R&D to company objectives; project selection and the R&D portfolio; control and evaluation of R&D; organization of R&D in the company and relations with other activities; organization of the laboratory; project scheduling; supervision in the laboratory; individual creativity and productivity; research on research.

The Wharton School, University of Pennsylvania

Technological Innovation and Entrepreneurship

Instructor: William F. Hamilton

Topics: technological innovation and entrepreneurship in perspective (technology and technological change, technological innovation and the innovative process, entrepreneurship and the entrepreneurs); venture analysis (the nature and sources of inventions, creating and identifying technological opportunities, screening methods and selection criteria, technical feasibility analysis, business feasibility analysis); planning for technological ventures (the business plan -- purposes and guidelines, technological forecasting and technology assessment, financing and finances, marketing and sales, organizational options, management and operations, legal issues); managing business growth (personnel practices and problems,

operations planning and control, strategies for success, cashing in); student projects -- class presentations and evaluations; the future of technological innovation and entrepreneurship (the changing environment -- public and private, technological innovation in new and established organizations, technological opportunities for the future).

Management of Technology

Instructor: William F. Hamilton

Faculty: business

Topics: technological innovation in the United States; emerging versus established technologies; strategic responses to technological change; the dimensions of technological innovation; technological forecasting and assessment; technology as a strategic corporate resource; technology strategy and planning; managing technological innovation; issues and options in R&D management; organizing for innovation; technological venture development.

School of Management, Syracuse University

Managing Innovative Products and New Ventures

Instructor: David Wilemon

Comment: focuses on the managerial processes necessary to develop and nurture innovative new products, technologies, and services in corporate and non-profit organizations.

Topics: importance of R&D, innovation, and new product development; innovation as a corporate philosophy; discovering alternative growth or innovation options; role of change as a catalyst and as a response to innovation; defining the vision of business: the most crucial issue in designing an innovation strategy; managing strategic fit issues; planning defendable new product development strategies; generating and evaluating a new product or venture idea; the role of technological strategies in new product development; organizational design options in managing innovation; dealing with ambiguity, coordination, and priority setting in R&D; new product and new technology development in the public sector; managing rapid growth and success: implications for innovation.

APPENDIX 4

SURVEY PARTICIPANTS

Deans of Engineering or Their Representatives

Pierre Bélanger
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University of Calgary

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University of Waterloo

Andrew Szonyi
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Michael Volker
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Business Faculties
Alain Albagli
University of Ottawa

Ronald Baecker
University of Toronto

Peter Banting
McMaster University

Yvor Gasse
Université Laval

Russell Knight
University of Western Ontario

Ed McMullan
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Michael Martin
Dalhousie University

Jean Robidoux
Université de Sherbrooke

Michael Skipton
Memorial University of Newfoundland

Albert R. Wood
University of Western Ontario

H. Clifton Young
University of Alberta

Science Faculty
Peeter Kruus
Carleton University

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4. David Vice, "Business Education: Striving for Excellence," speech at Memorial University Partner's Dinner, St. John's, Newfoundland, 7 May 1986.

5. Yvon Gasse, "A Strategy for the Promotion and Identification of Potential Entrepreneurs at the Secondary Level," in Frontiers of Entrepreneurship Research, ed. J.A. Hornaday, E.B. Shils, J.A. Timmons, and K.H. Vesper (Wellesley, Mass.: Babson College, Center for Entrepreneurial Studies, 1985), 538-548.

6. T.E. Clarke, R&D Management Bibliography -- 1981 (Vancouver: Stargate Consultants Limited, 1981).

7. K.H. Vesper, Entrepreneurship Education -- 1985 (Wellesley, Mass.: Babson College, Center for Entrepreneurial Studies, 1985), 137.

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